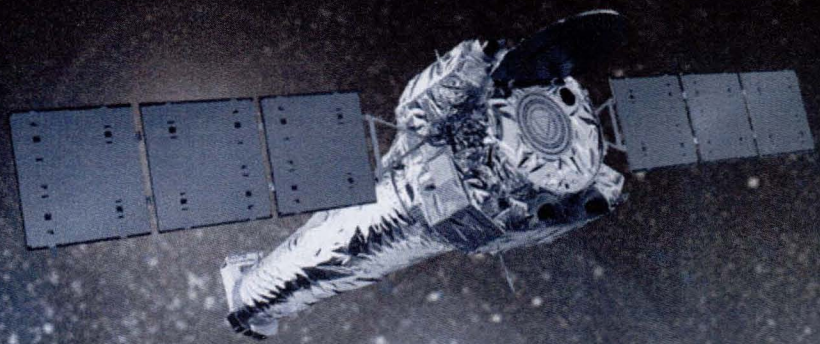
Abstract:

The Chandra X-Ray Observatory was designed for three years of operation with a goal of five. Launched on July 23,1999 this Great Observatory is now beginning its 8-th year of operation. The Observatory is an outstanding example of one of NASA's technical and scientific success stories. The reasons for that success will be reviewed and some of the outstanding scientific discoveries will be presented.

MSFC-455 -Presentation

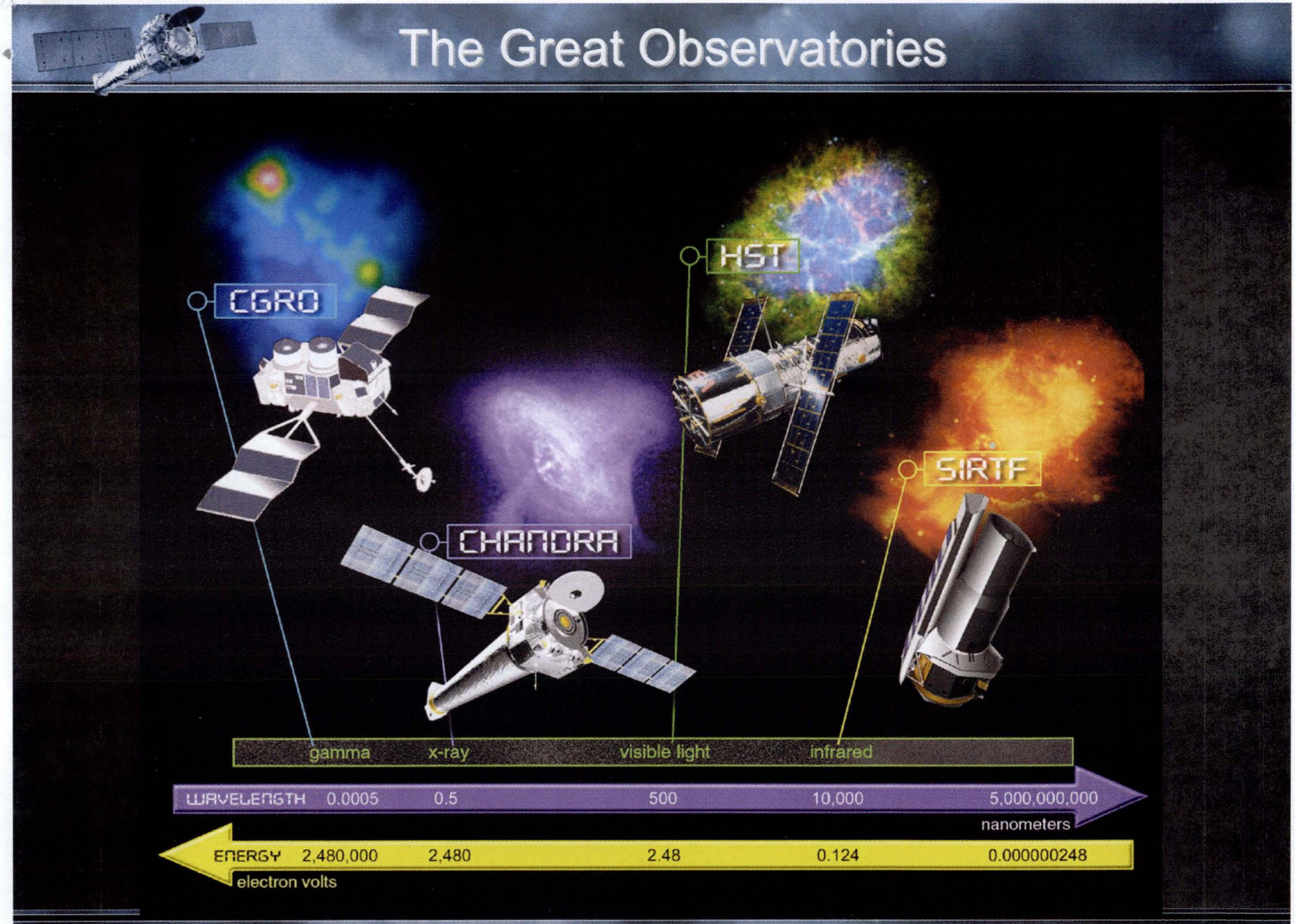


The Chandra X-Ray Observatory

An Overview of its Success

September 18, 2007
Martin C Weisskopf

The Great Observatories



The Beginning - 1976

- 1976 – Proposal was submitted
  - This was the "formal" beginning

PROPOSAL TO

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FOR THE

STUDY OF THE 1.2 METER X-RAY TELESCOPE

NATIONAL SPACE OBSERVATORY

(Volume I - Technical Proposal)

P605-4-76

For the period 1 July 1976 to 30 September 1978

Principal Investigator
Dr. Riccardo Giacconi
Associate Director for
High-Energy Astrophysics Division

Co-Principal Investigator
Dr. Harvey Tananbaum

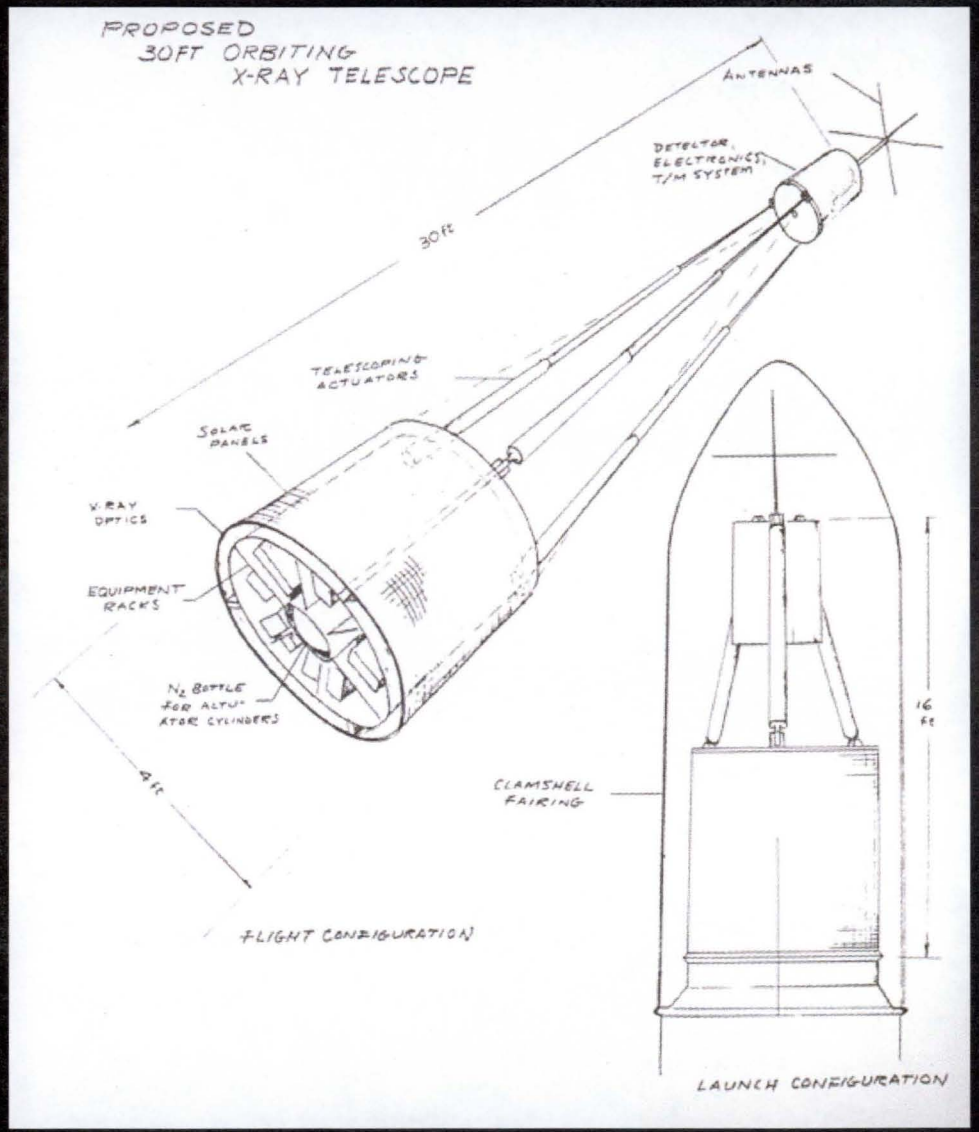
Co-Investigators
Dr. P. Gorenstein
Dr. R. Harnden
Dr. P. Henry
Dr. E. Kellogg
Dr. S. Murray
Dr. H. Schnopper
Dr. L. VanSpeybroeck

April 1976

Smithsonian Institution
Astrophysical Observatory
Cambridge, Massachusetts 02138

Director: Dr. George B. Field Assistant Director: Mr. John G. Gregory

The Smithsonian Astrophysical Observatory
and the Harvard College Observatory
are members of the
Center for Astrophysics



A Proposal for

AN EXPERIMENTAL PROGRAM
OF EXTRA-SOLAR X-RAY
ASTRONOMY

Prepared for

National Aeronautics and Space Administration
Washington 25, D. C.

Prepared by

American Science and Engineering, Inc.
11 Carleton Street
Cambridge 42, Massachusetts

25 September 1963

Approved:

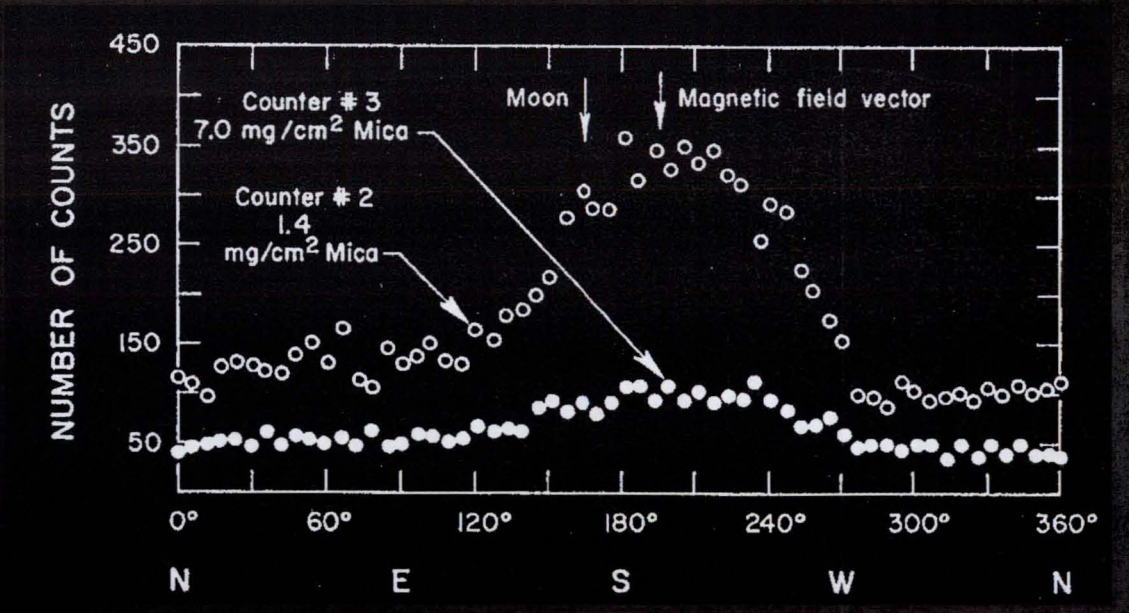
Riccardo Giacconi
Vice President
Space Research and Systems Division

This document consists of 75 pages.
Copy No. 4 of 7 Series A

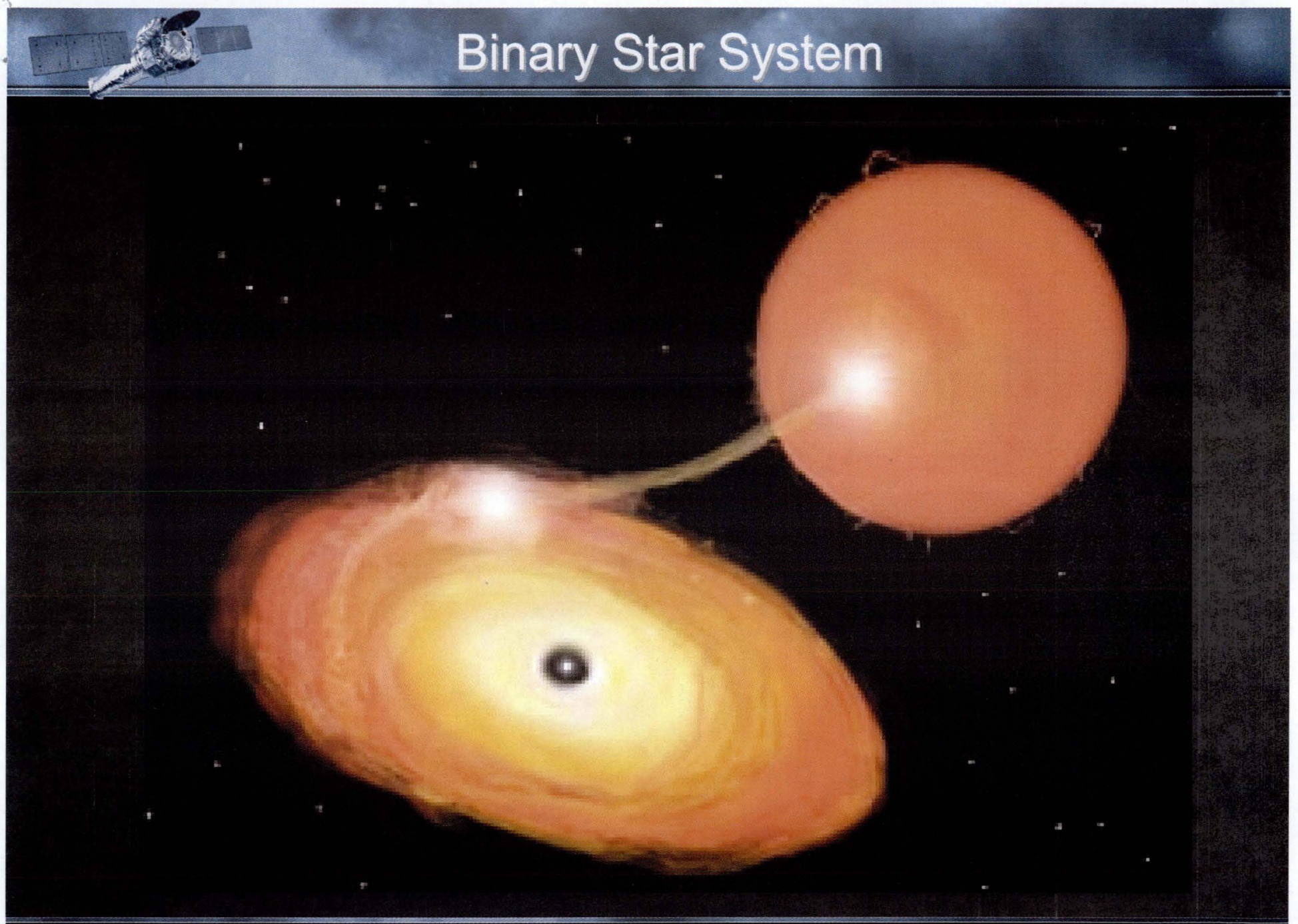
ASE Log No. 63-104-4

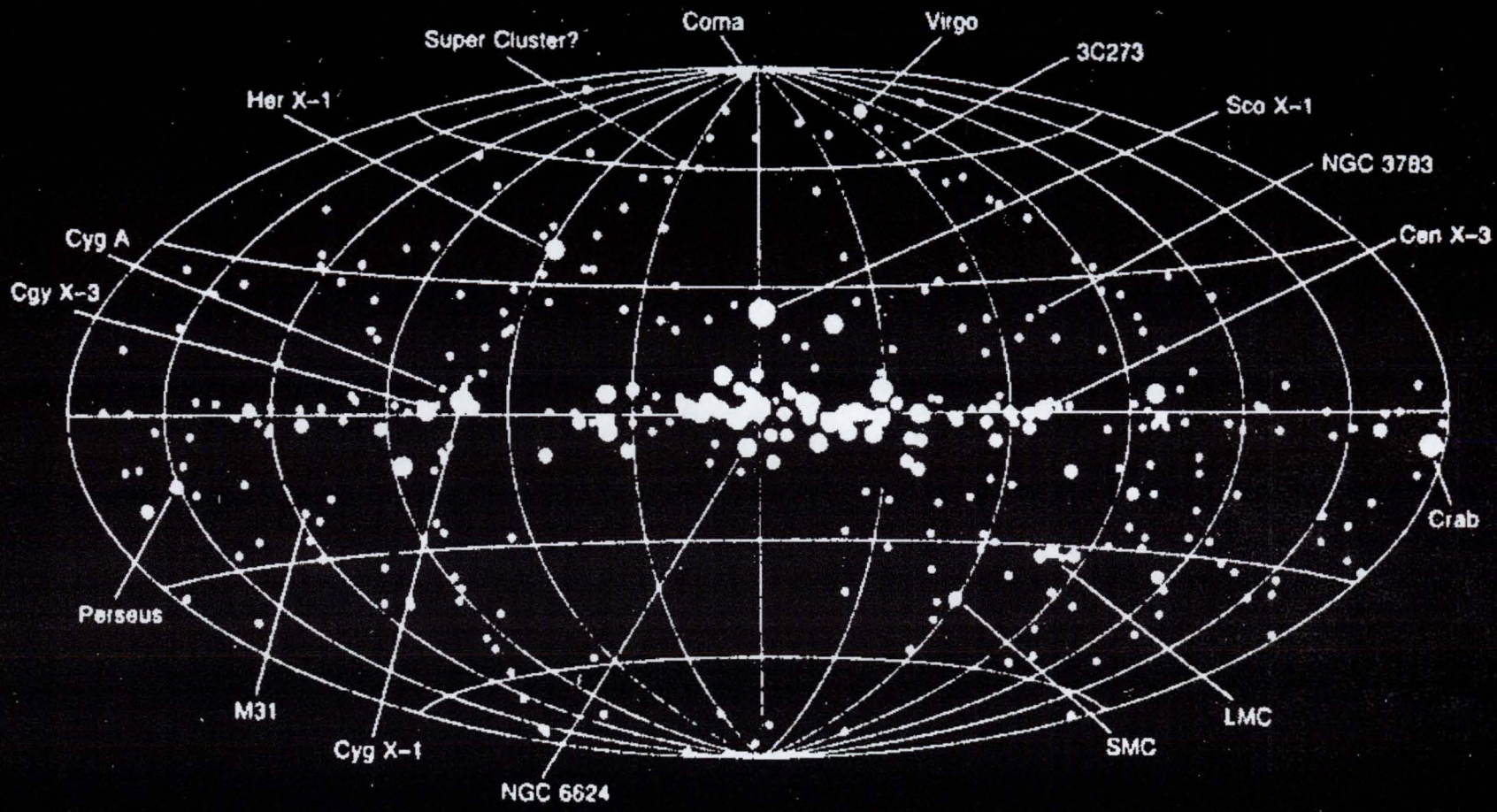
X-Ray Astronomy

- Solar Studies in late 40's
  - Solar corona produces X-Rays
- Discovery of first extra-solar source in 1962
  - Also discovery of faint glow - the "diffuse" background



Binary Star System



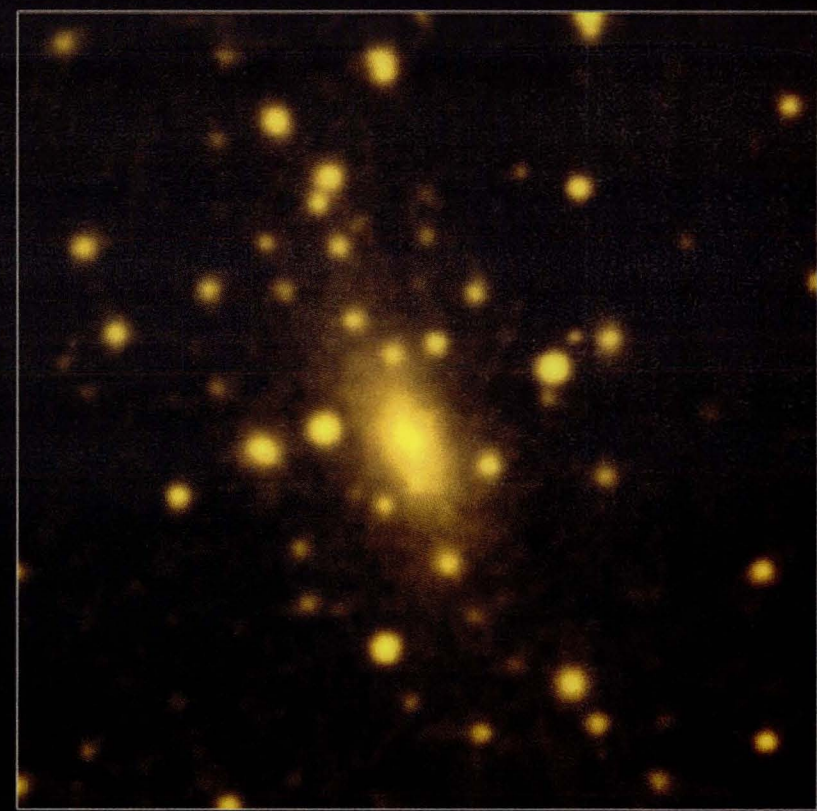


Uhuru (SAS-1) Conducted the First All Sky Survey of Cosmic X-Rays in 1971

X-Ray Astronomy

- We now know that most of the matter that we "see" is visible to us from its X-Ray emission
- The bulk of this matter is hot, X-Ray-emitting, gas in the great galaxy clusters

CHANDRA X-RAY

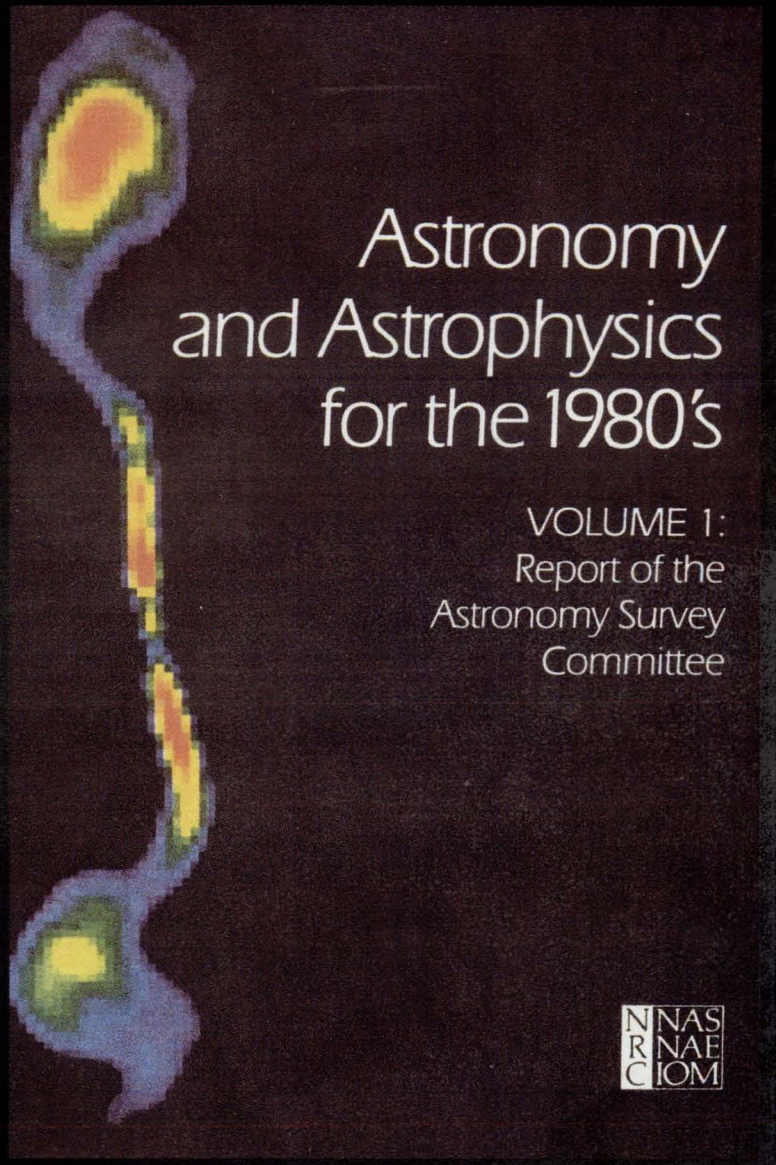


DSS OPTICAL

The Third Decadal Survey - 1981

Major New Programs:

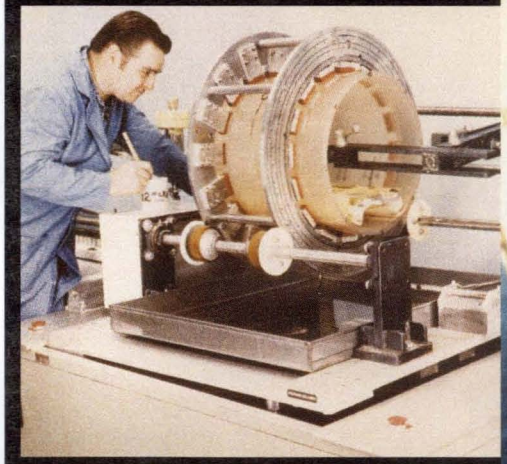
#1: An Advanced X-Ray Astrophysics Facility (AXAF)

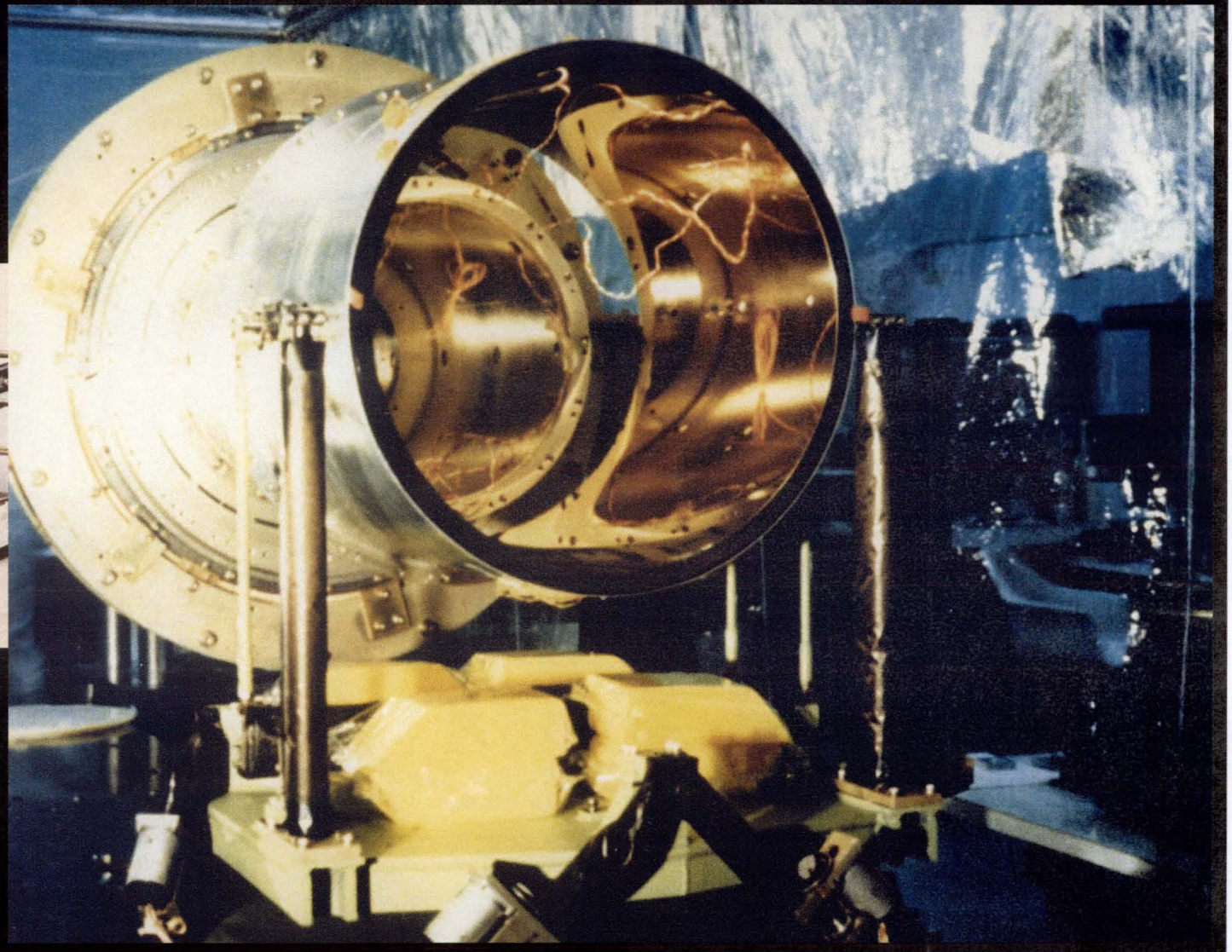


The Technology Mirror Assembly

- Single mirror pair
- Scaled (2/3) Version of innermost mirrors
- 6-m focal length
  - Allowed for testing in existing test facility
- 0.41-m element length
- 0.42-m diameter
- Gold coated (baseline at the time)

The Technology Mirror Assembly



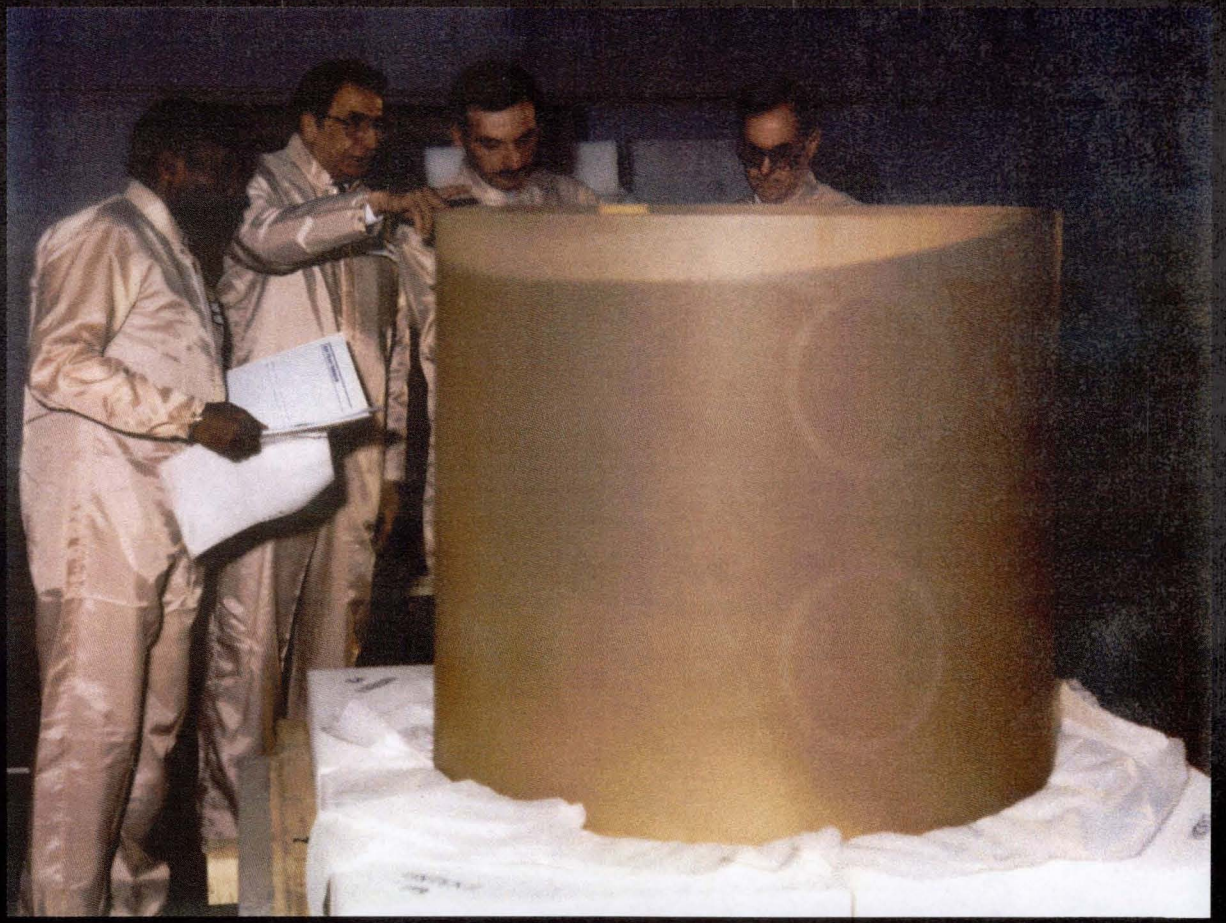


The Technology Mirror Assembly

- First delivery July 1985
  - Resolution better than 0.5”
  - However, near angle scattering
- Second delivery Jan 1989
- Final results were great
  - E.g. FWHM from 0.36” – 0.68”
  - Encircled energy as predicted

Flight Mirror Blanks

- Initiated purchase in 1987

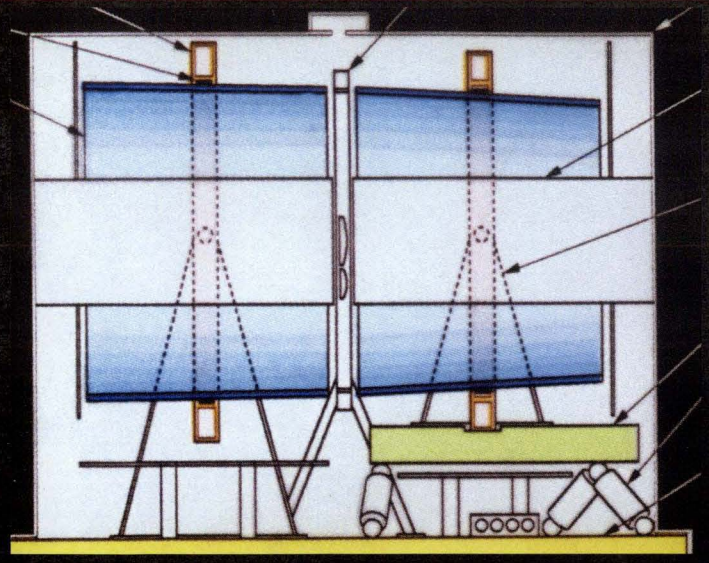


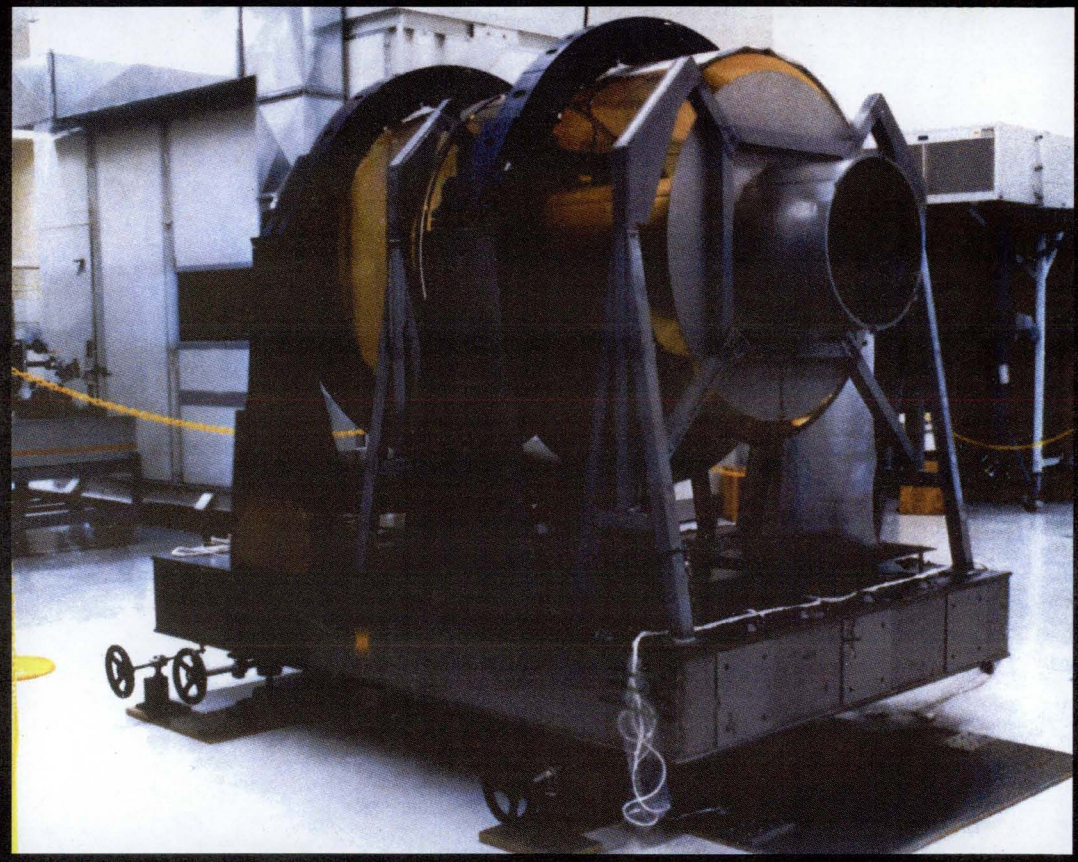
Other Milestones

- Prime contractor selection – 1988
- “New Start” - 1988
- Selection of the Science Center – 1991
- Started the “VETA” program - 1988
  - Verification Engineering Test Article

VETA

- P1/H1 – uncoated and uncut





- Needed test facility at least one year earlier than planned!

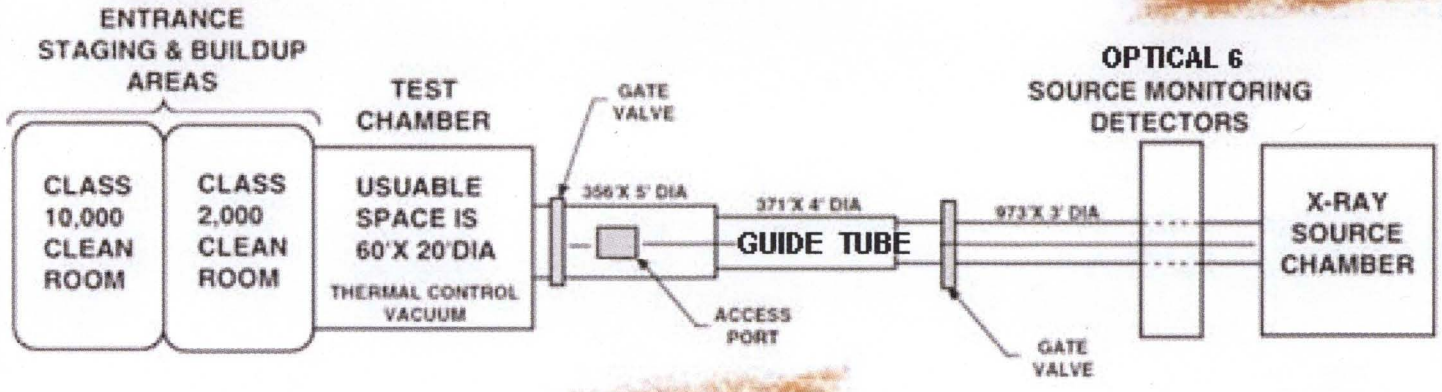
The X-Ray Calibration Facility (XRCF)

X-RAY CALIBRATION FACILITY

ISOLATED FACILITY CONTROL SYSTEM

SEGMENTED VACUUM SYSTEM

ADVANCED DATA HANDLING SYSTEM

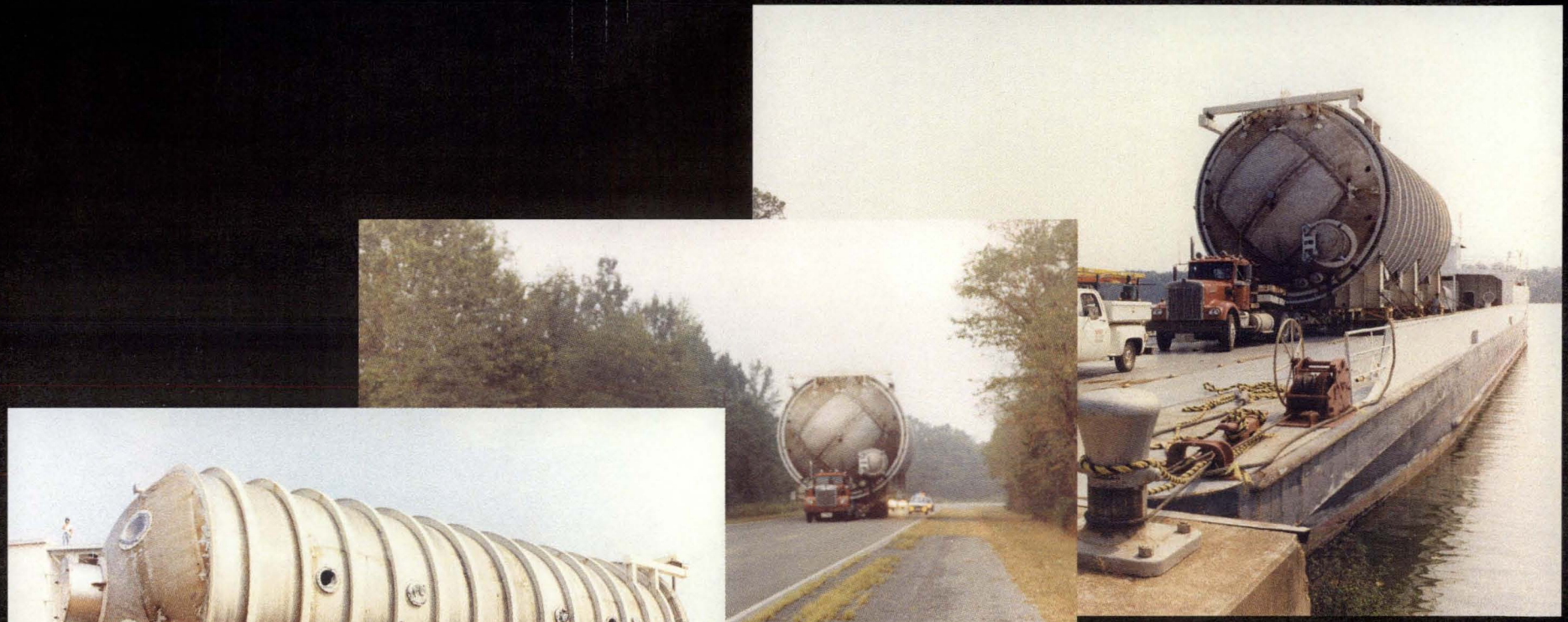


POWER SYSTEM WITH EMERGENCY BACK UP

VIDEO & AUDIO COMMUNICATION SYSTEM

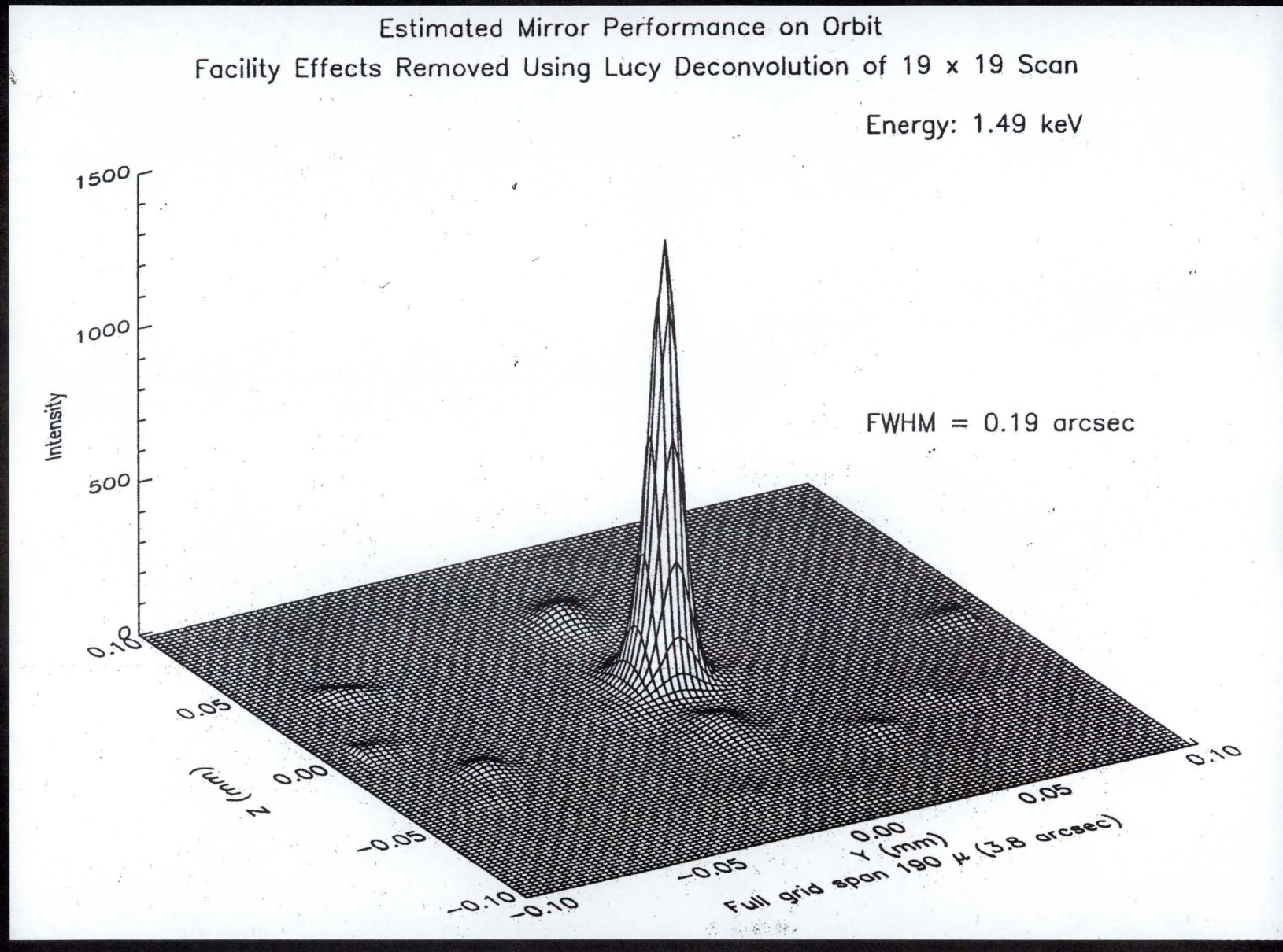
VERSATILE X-RAY SOURCE & DETECTION SYSTEM

The X-Ray Calibration Facility (XRCF)

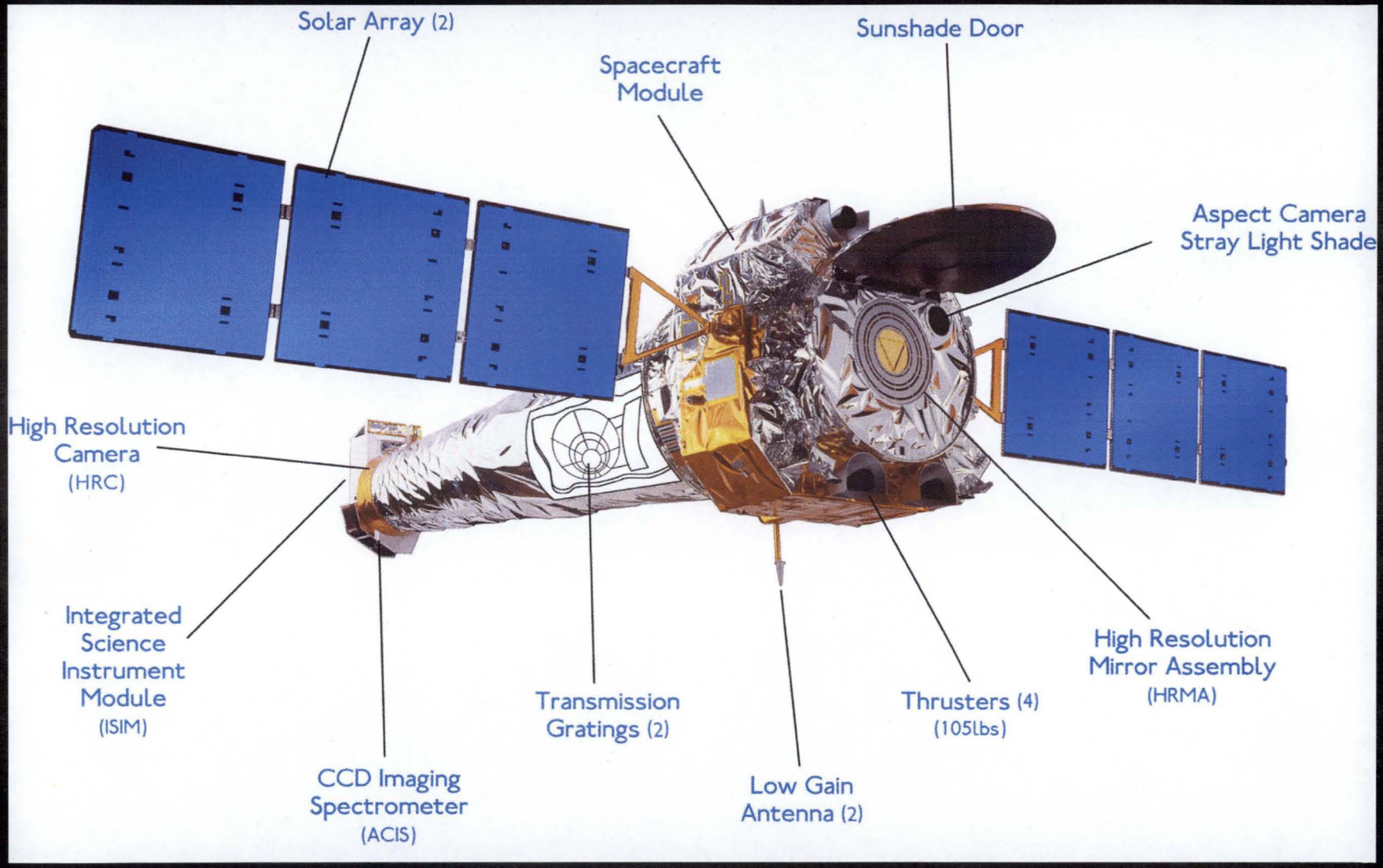


The X-Ray Calibration Facility (XRCF)

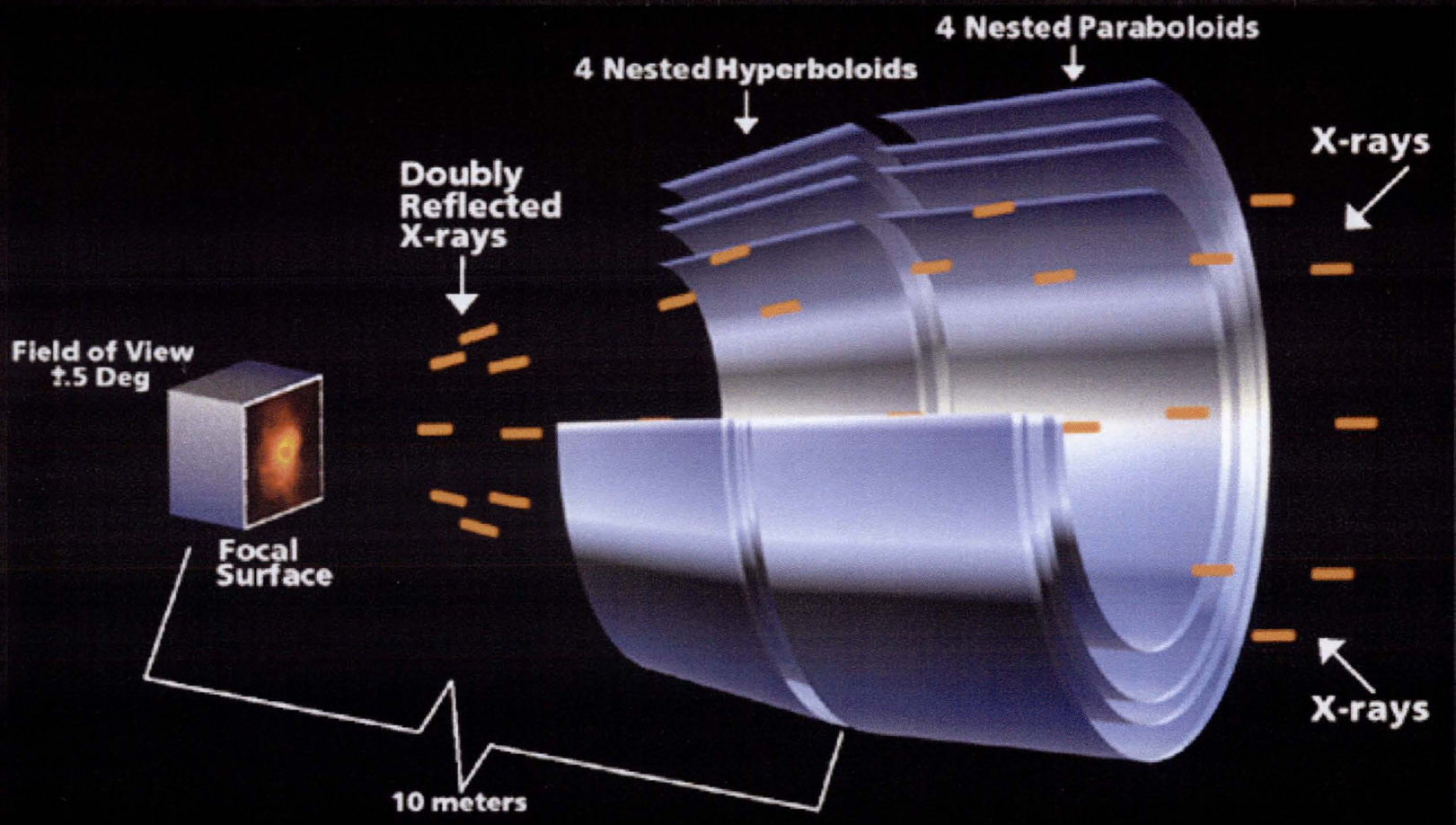
The Veta Tests - 1991



The Observatory



Chandra Optics

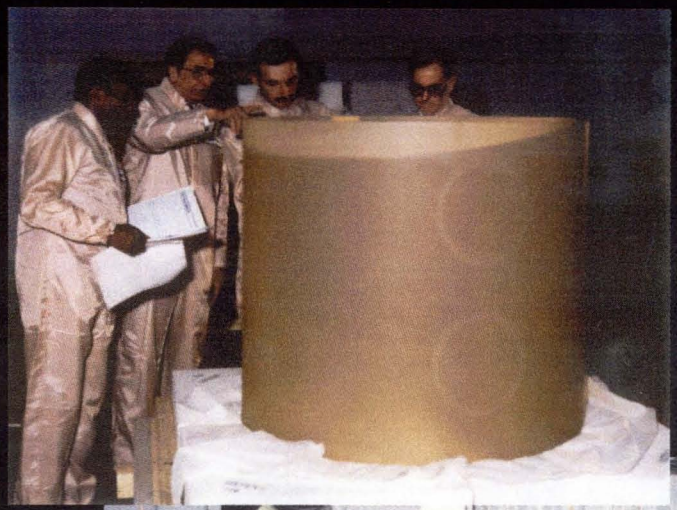


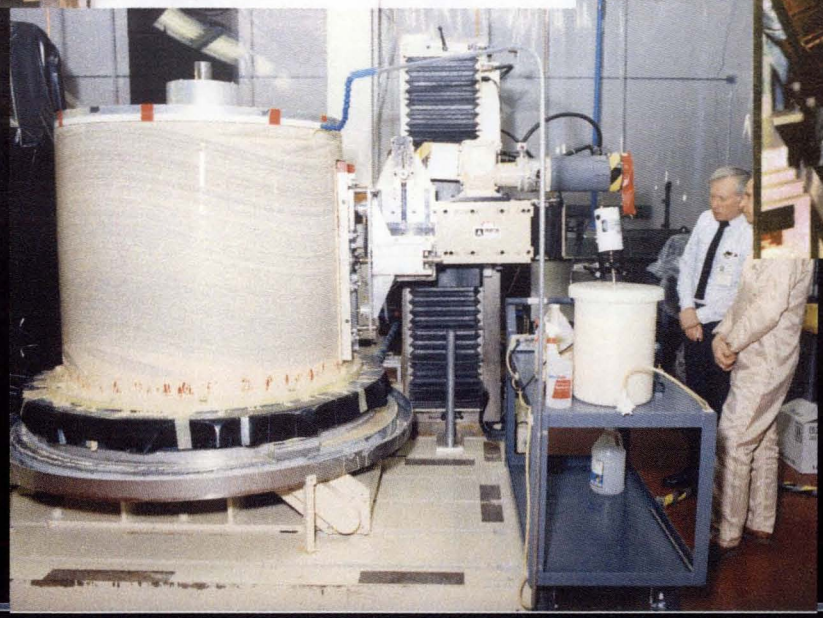
Mirror elements are 0.8 m long and from 0.6 m to 1.2 m diameter

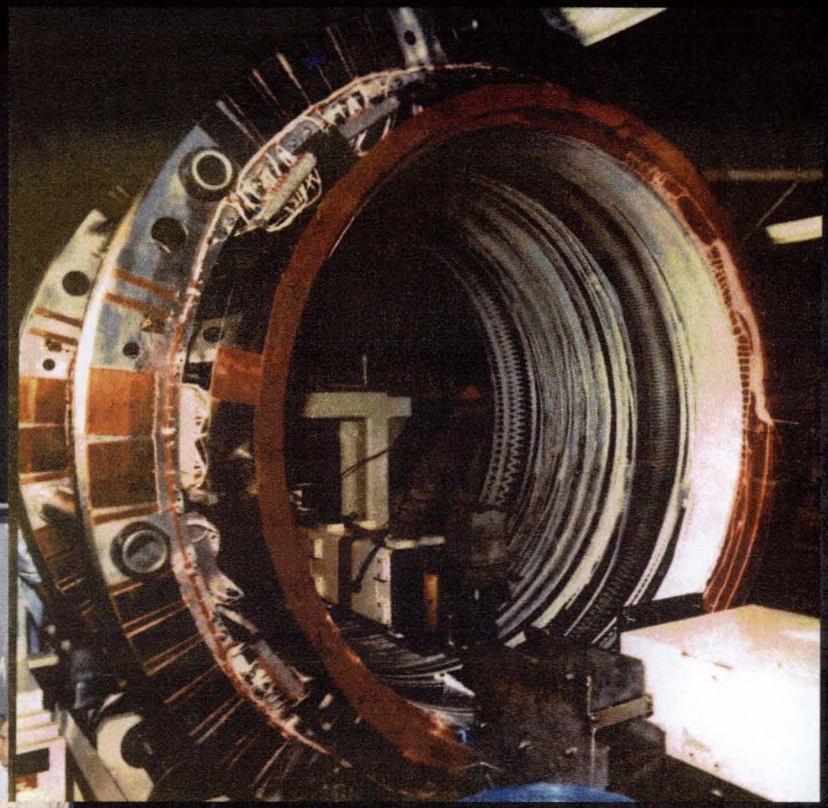
Properties

- Diameters: 0.65, 0.87, 0.99, 1.23 m
- Segment length: 0.84 m
- Mass: 1484 kg
- Focal length: 10 m
- Plate scale: 49 μm/arcsec
- Field-of-view: 30 arcmin diameter
- Clear area: 1145 cm^2
- Resolution: 0.2 arcsec FWHM
- Surface Roughness: 1.5-3.5 Å rms
- Coating: iridium

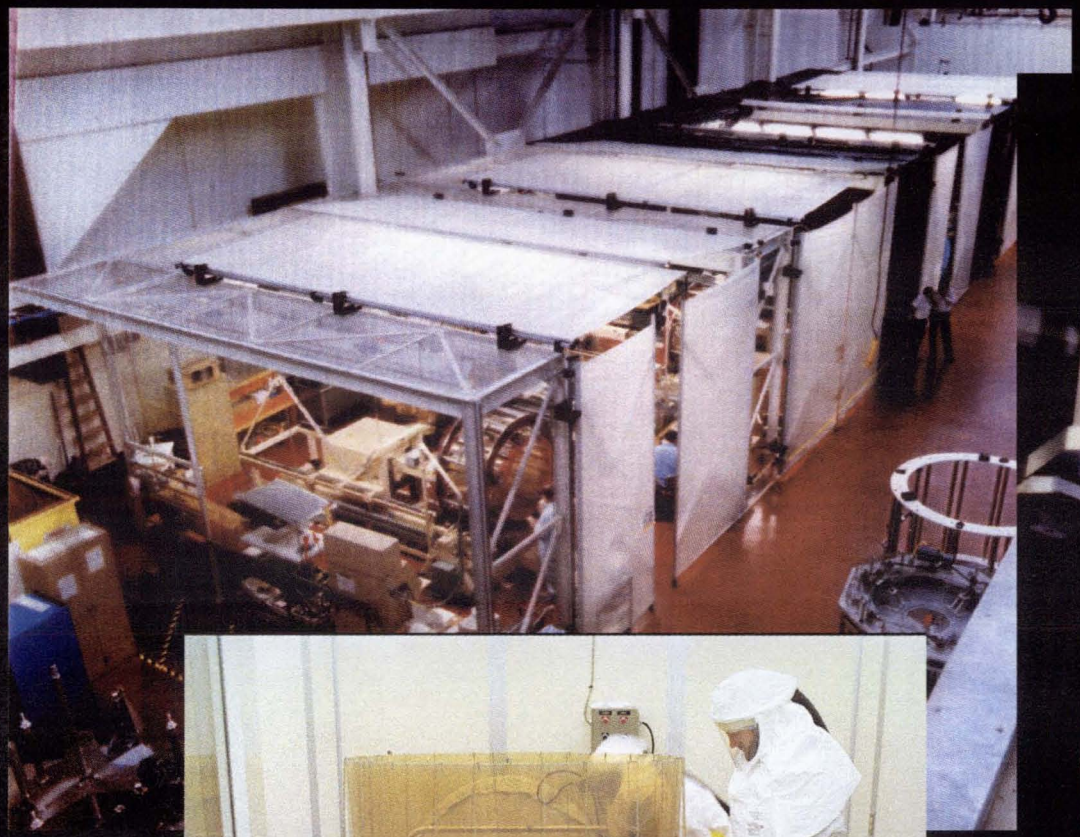
Optics

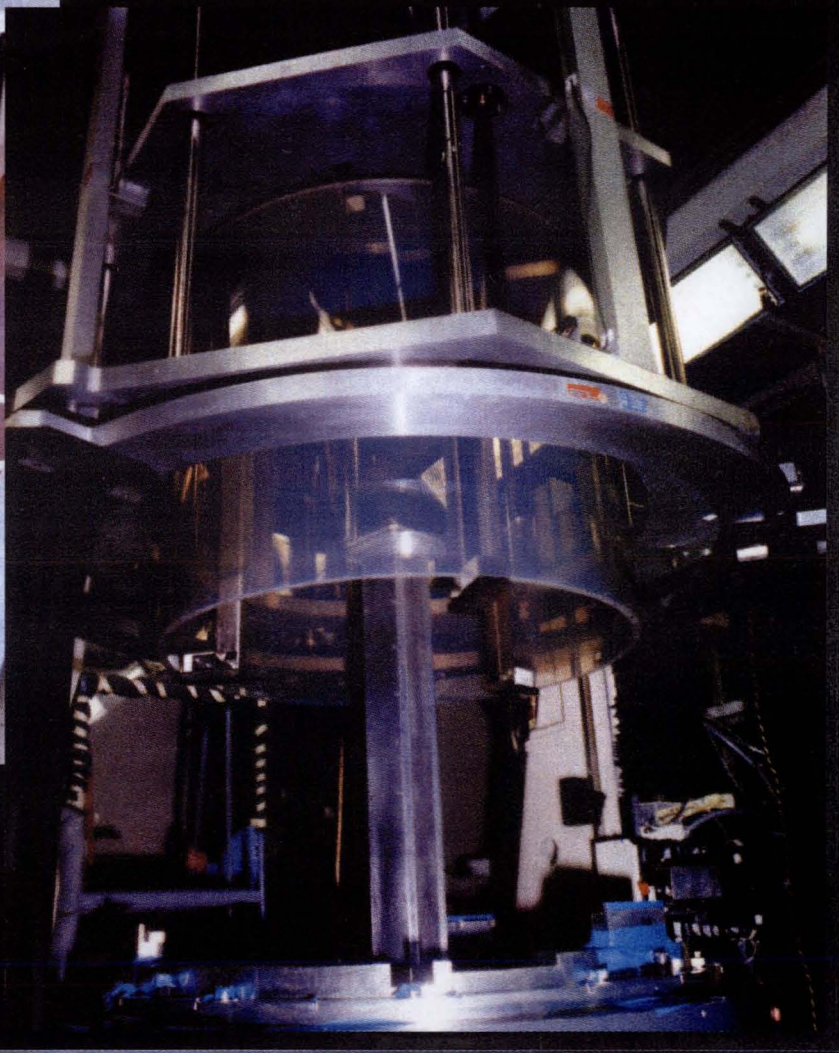




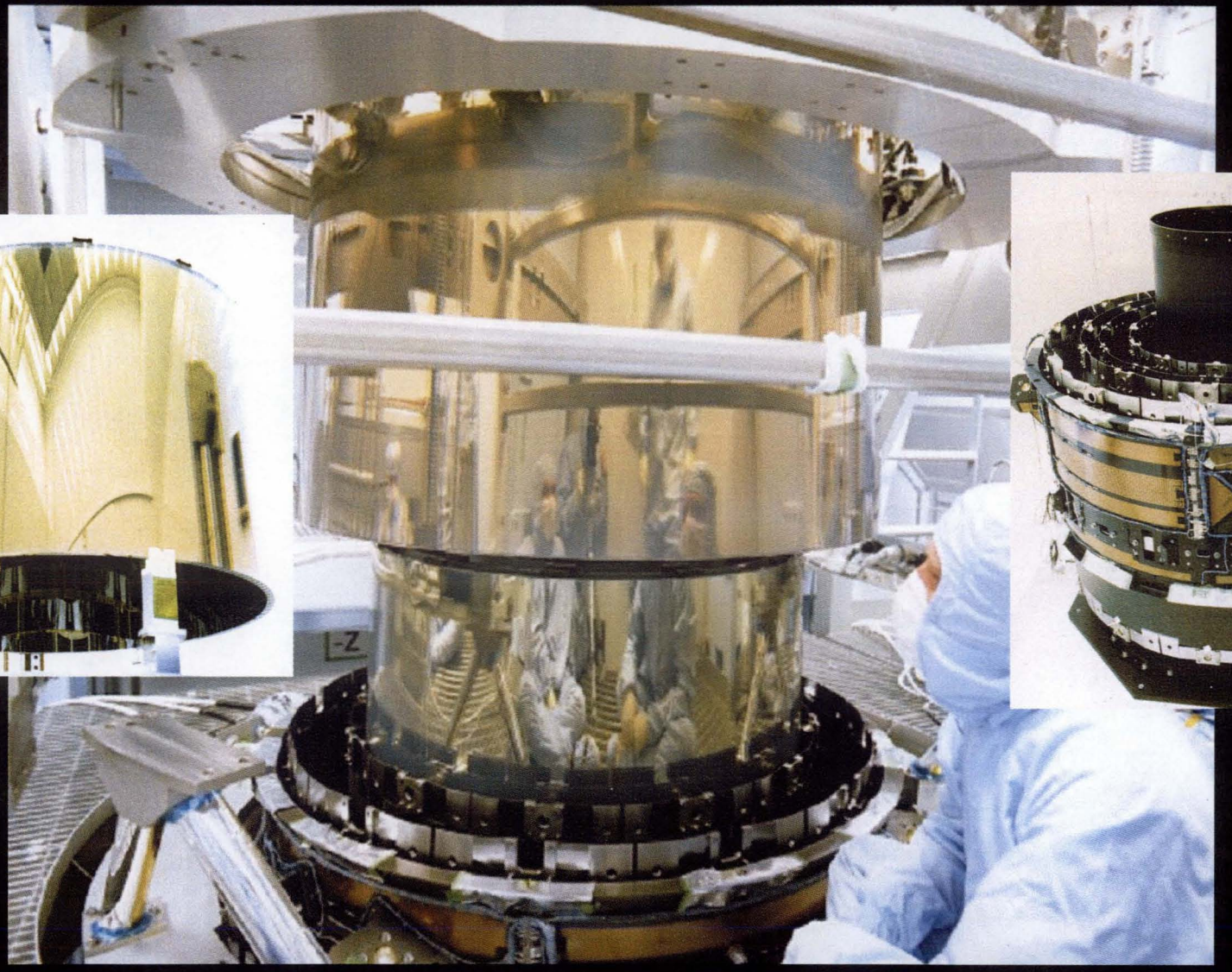


Optics

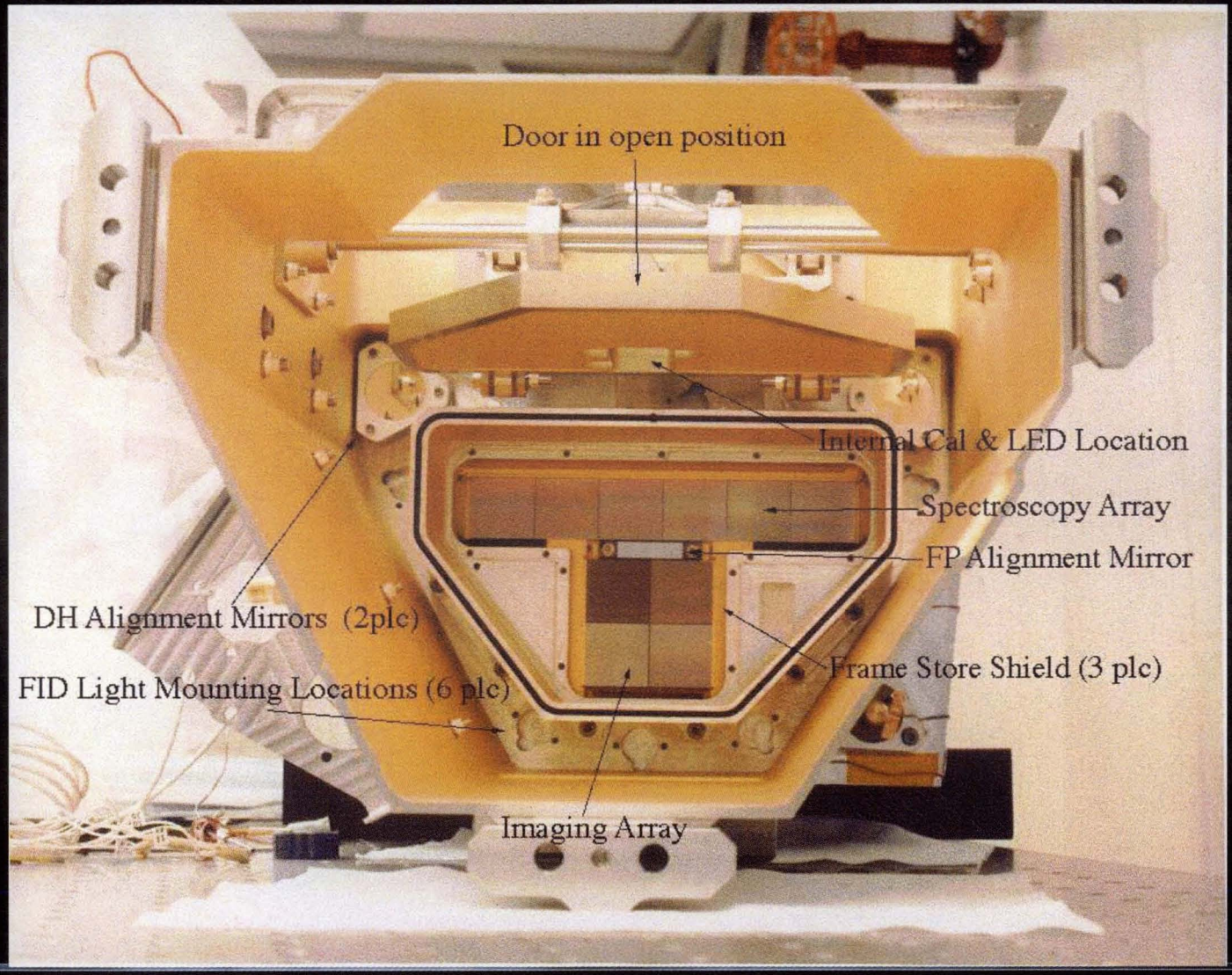




Telescope



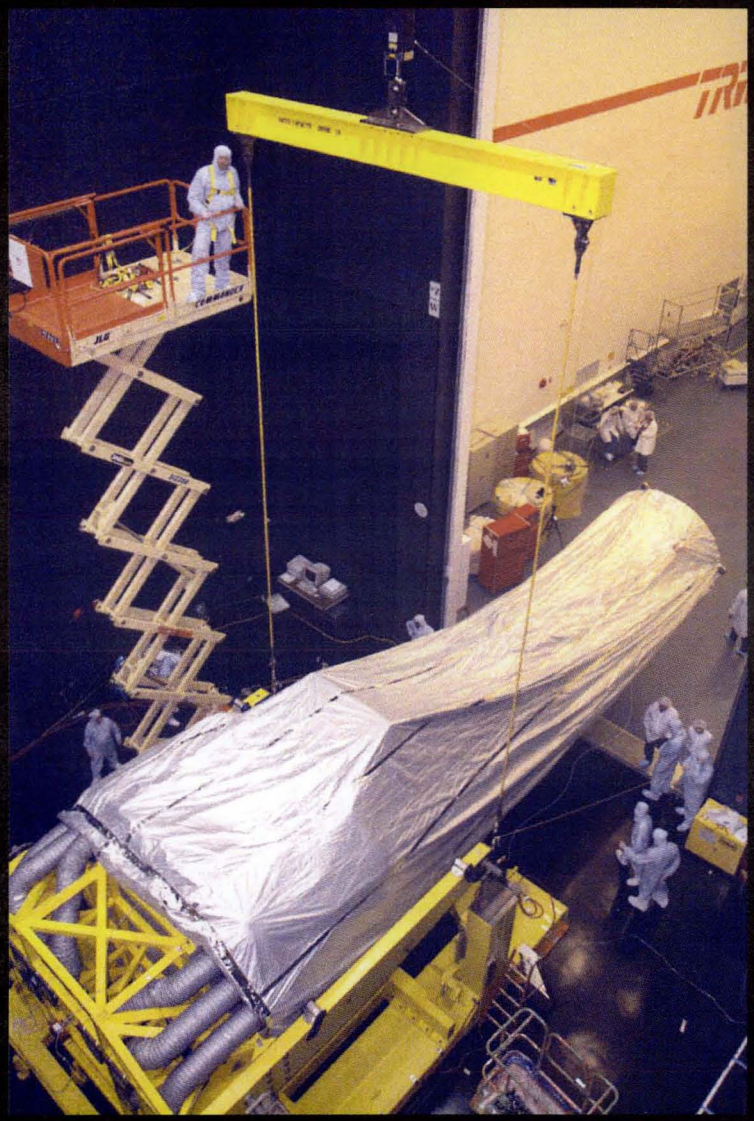
The ACIS Instrument



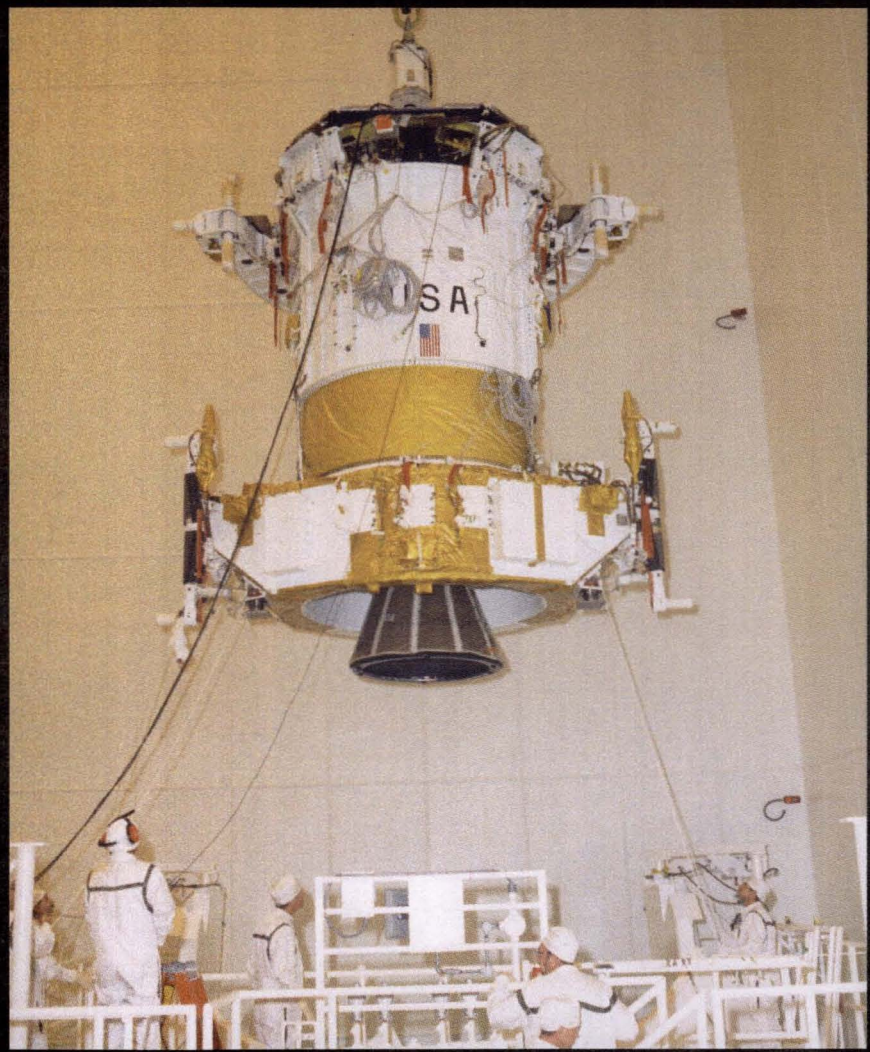
X-ray Calibration (1996-1997)

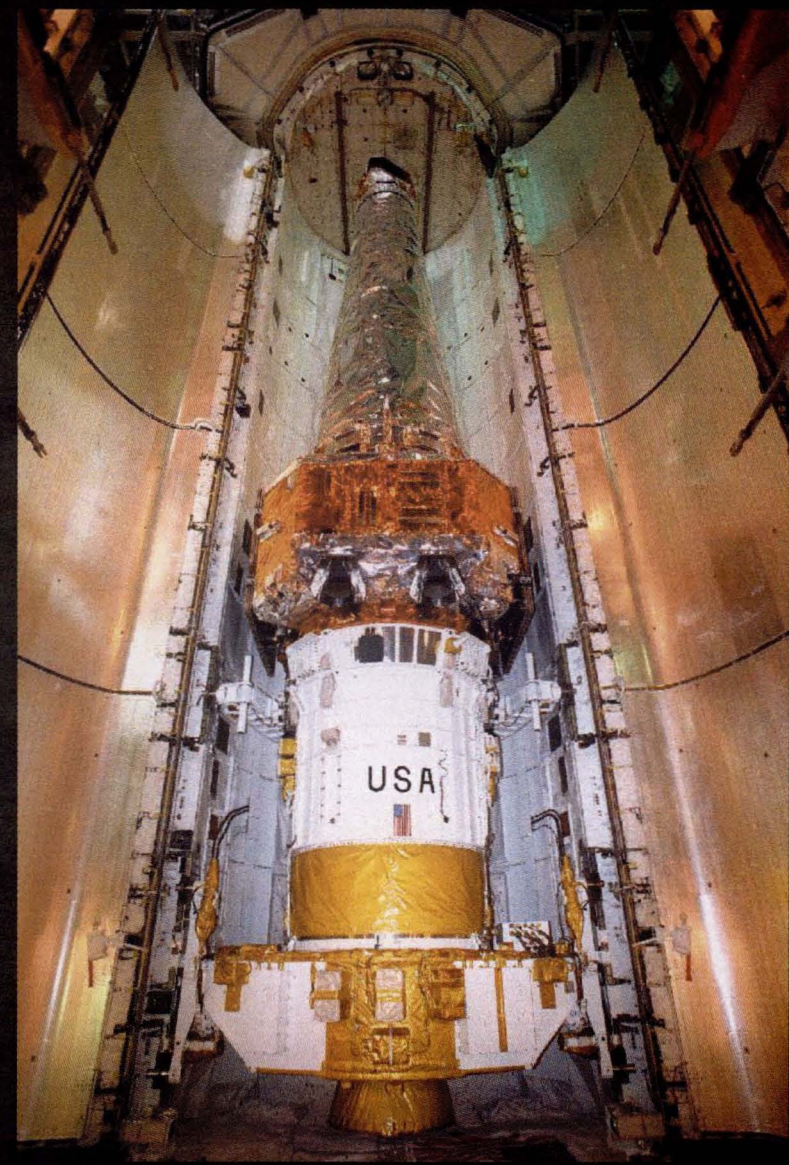
X-ray Calibration Facility

On to the Cape – Feb 1999



With Upper Stage





Chandra With Chandra

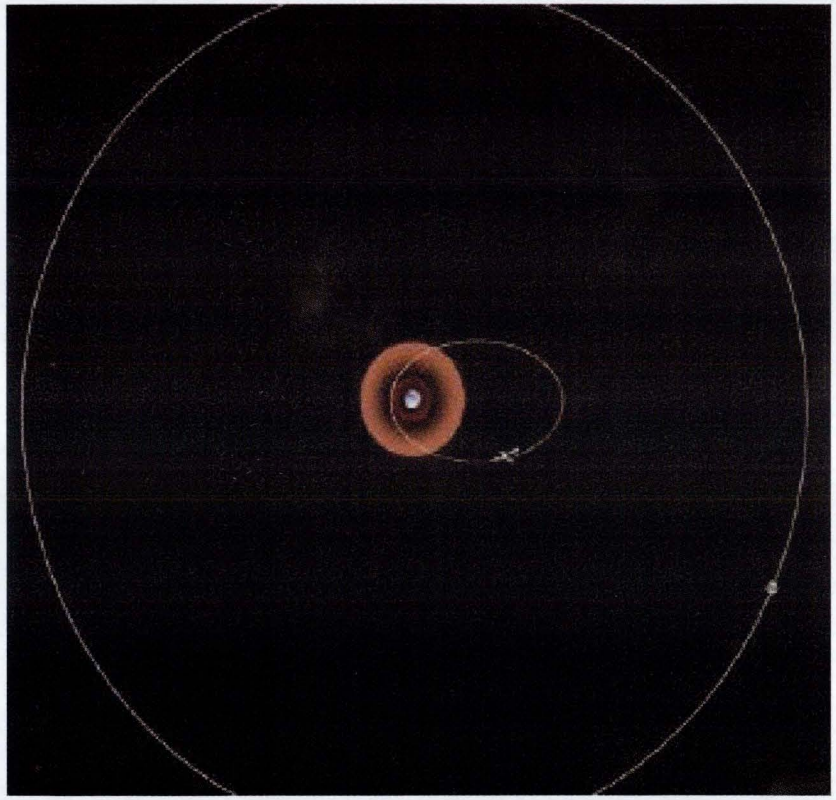
The Crew

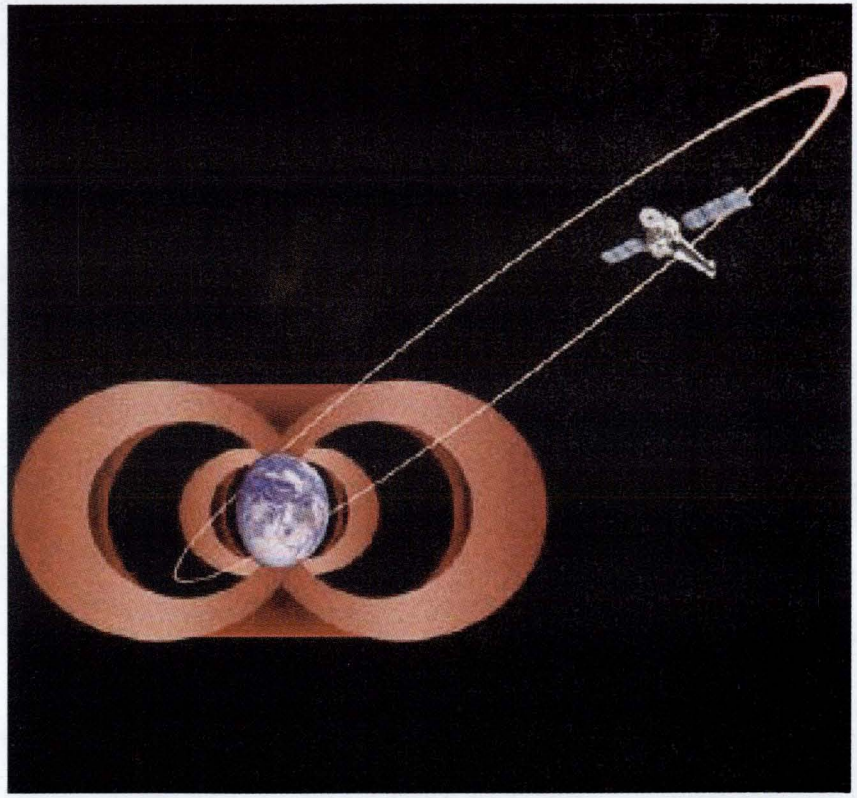
Three Launch Attempts

- Mon/Tue July 19/20
  - Sensor spike hydrogen in the engine compartment
- Wed/Thurs July 21/22
  - Lightning in the vicinity
- Thurs/Fri July 22/23
  - Third time is a charm

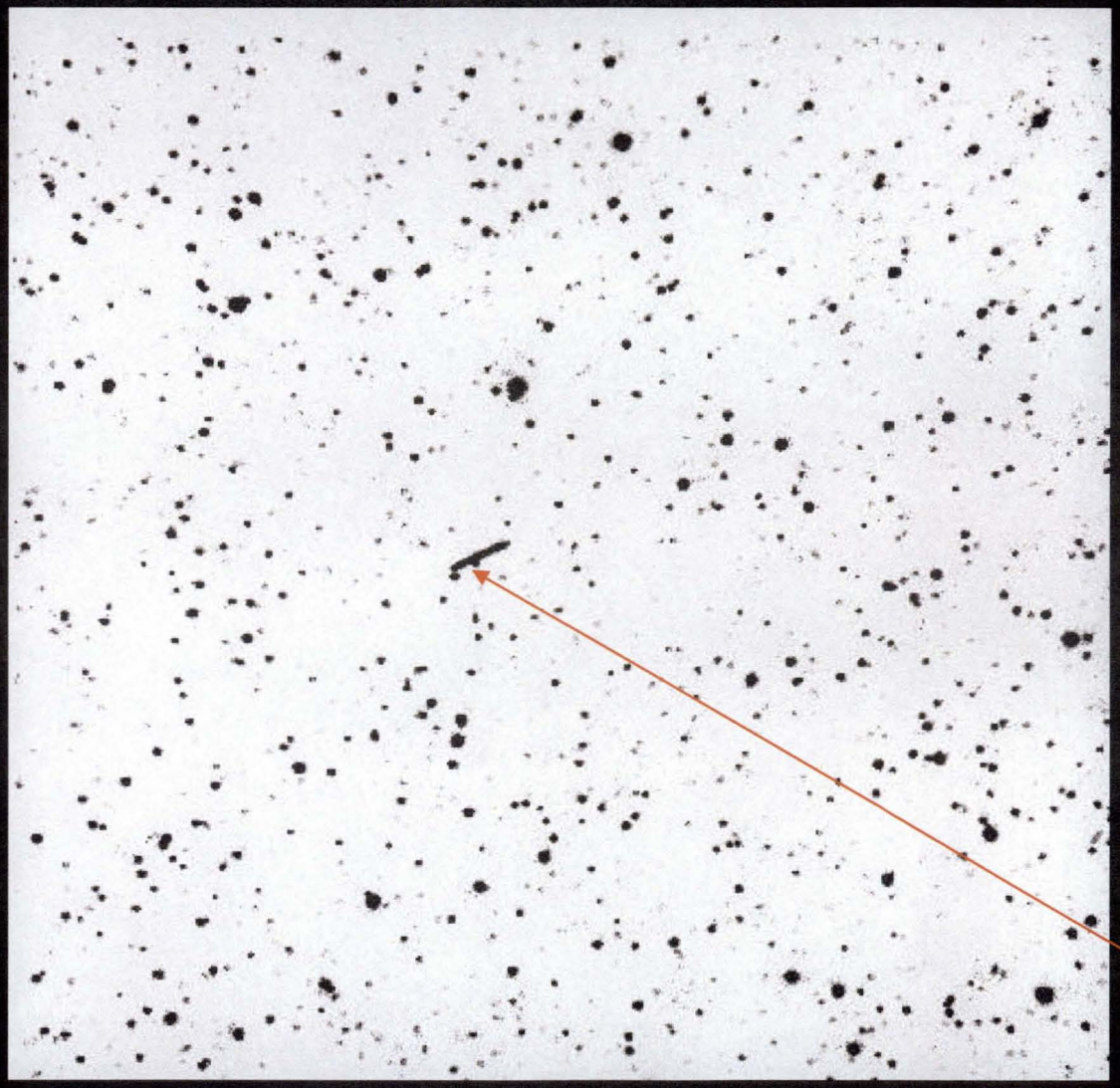
Launch at last! July 23 1999 @ 12:31 a.m.

The Orbit



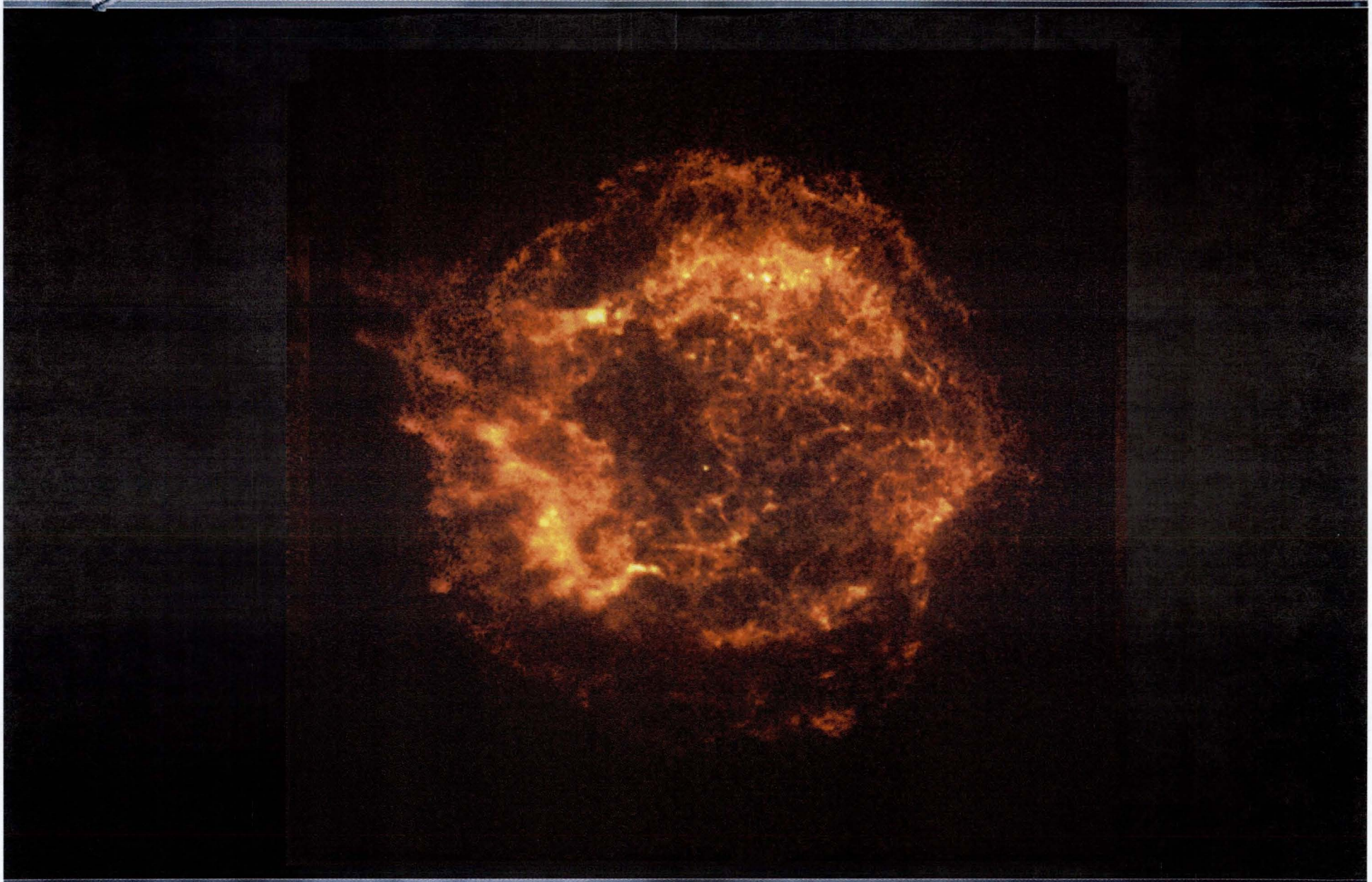


Chandra In Orbit!

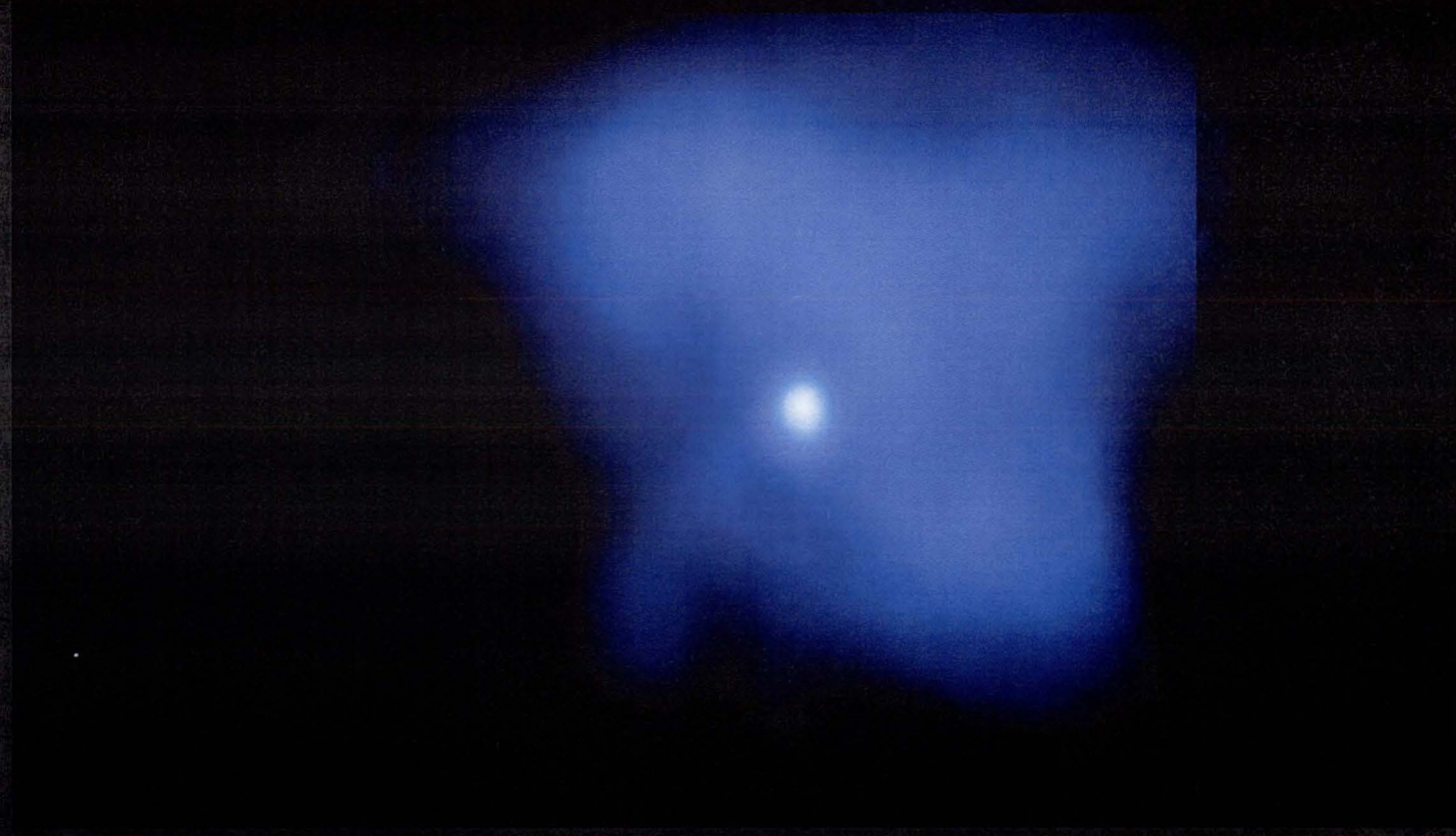


First Light

First Light – Cas A

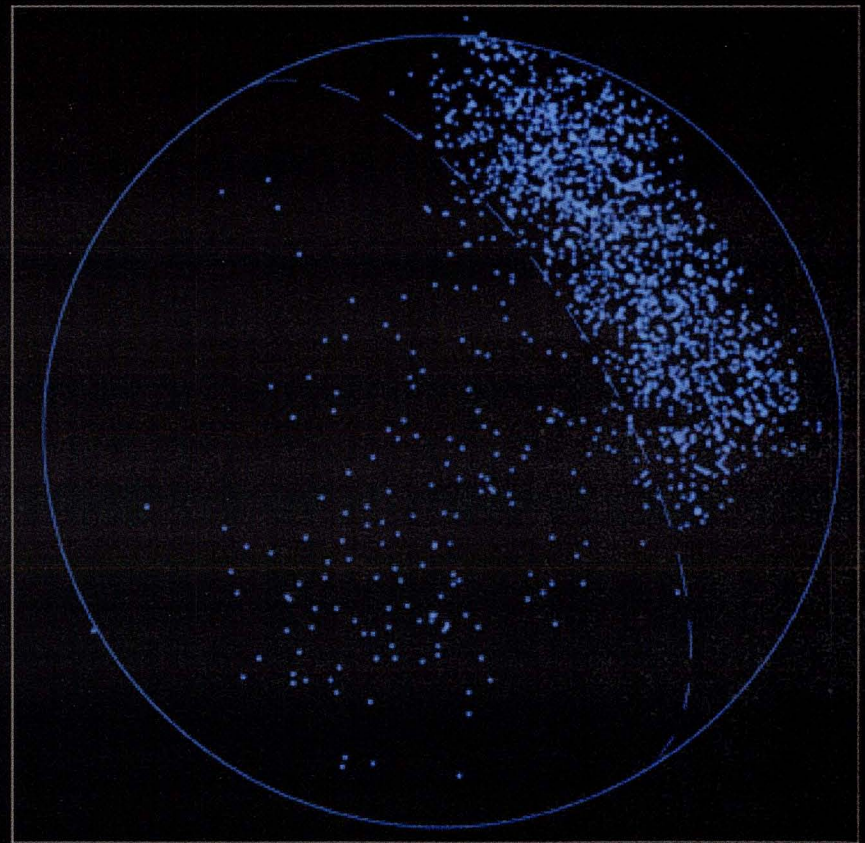


Crab Nebula



The Moon

OPTICAL



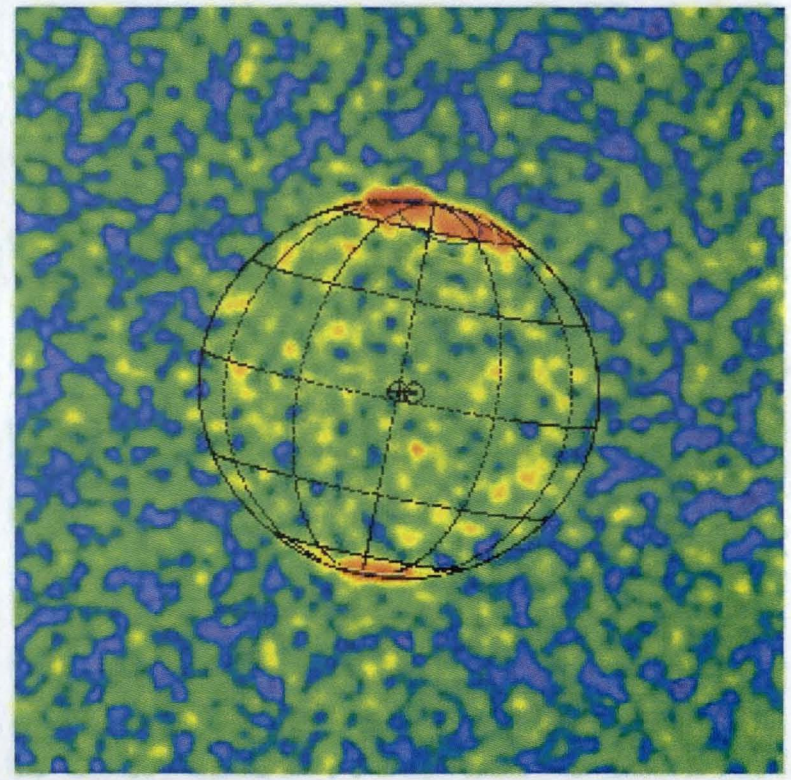
X-RAY

Optical: Robert Gendler; X-ray: NASA/CXC/SAO/J.Drake et al.

Planets

All planets, other than Uranus, are X-ray sources!

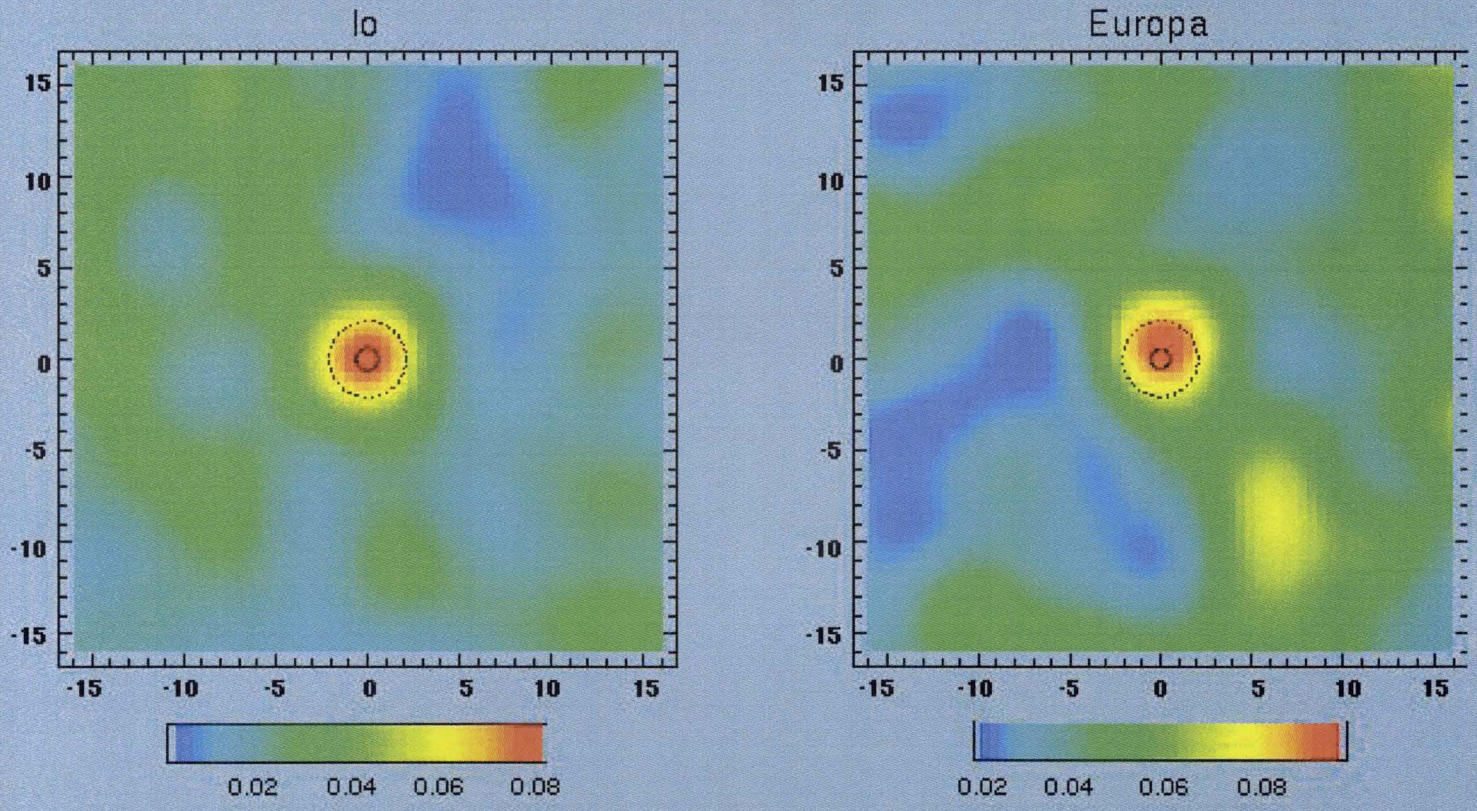
- Jupiter
  - Hot spots at high latitudes
    - *Big surprise*
  - Pulsates (45 minute period)



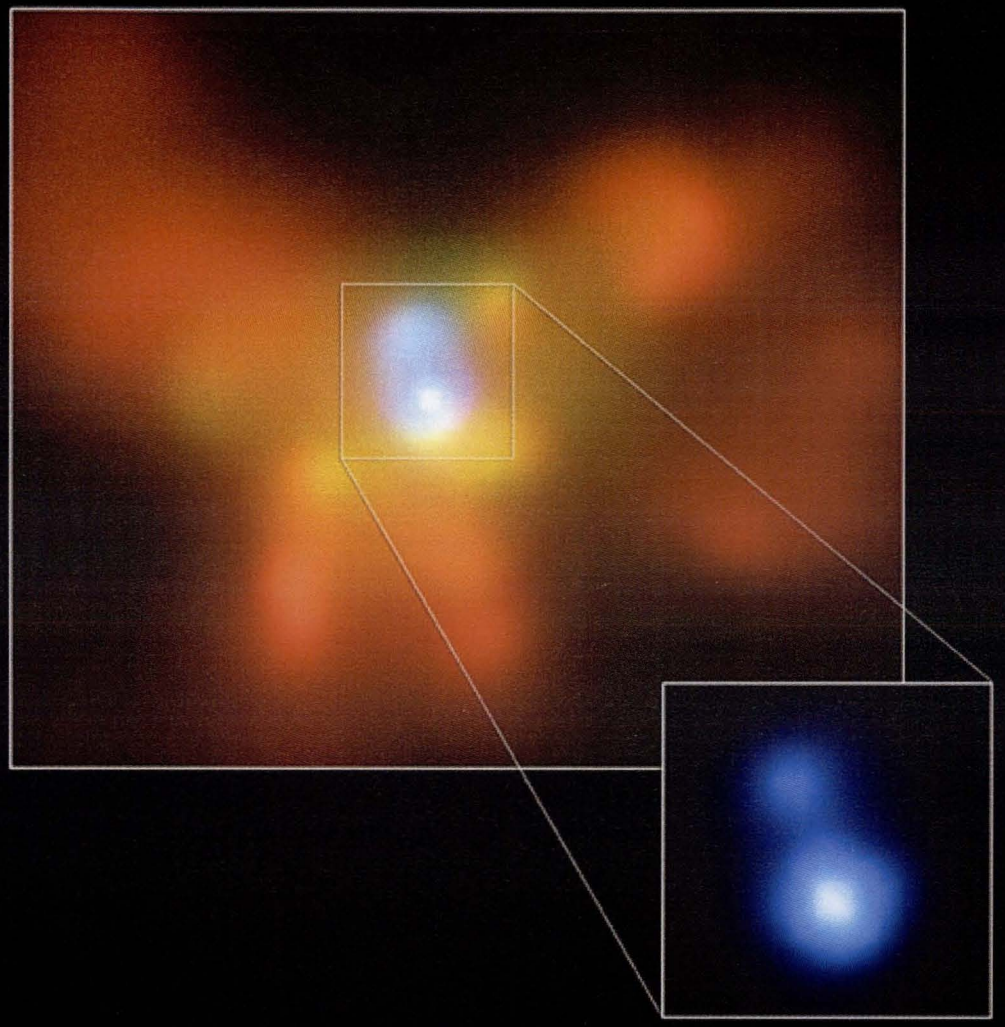
Gladstone et al.(2002) Elsner et al. (2002)

Jupiter's Moons

Chandra X-ray Observatory ACIS-S Images of Io and Europa



Double Quasar



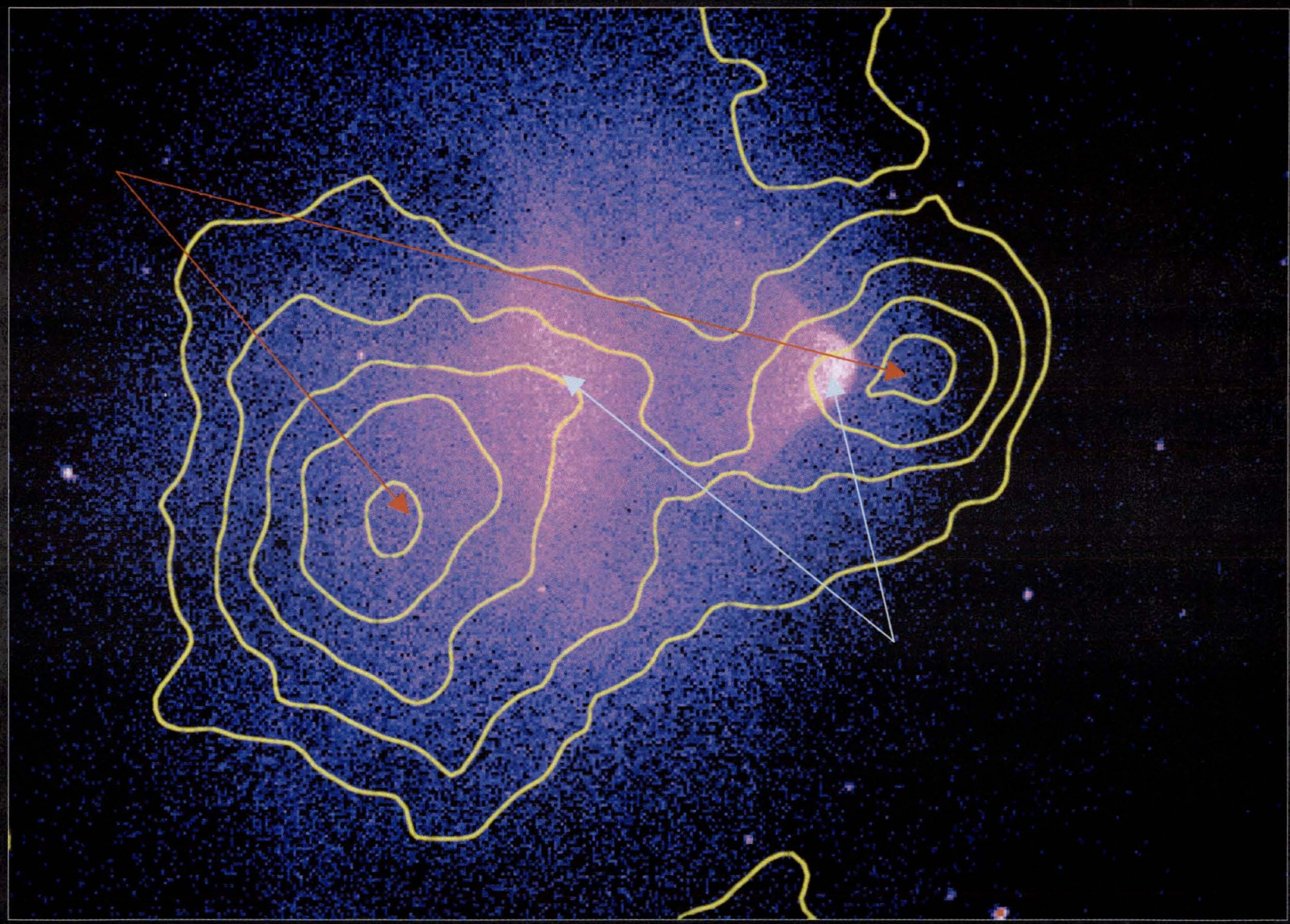
AIAA 2007

NASA/CXC/MPE/S.Komossa et al

The Deep Surveys

- 1-Million seconds on Chandra Deep Field-South (CDF-S) and 2-Million on CDF-N
  - *Probe is 80 times deeper at low energies*
  - *800 times deeper at hard energies*
  - *All data publicly available*
- CDF-N detects about 500 discrete sources and 6 extended sources

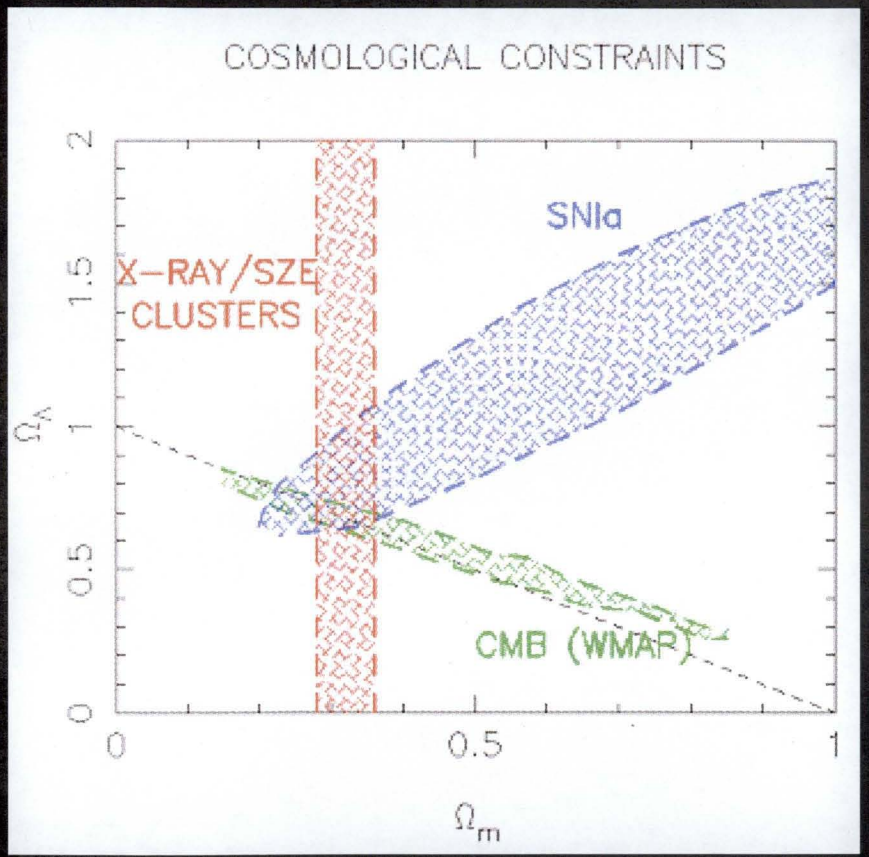
Dark Matter

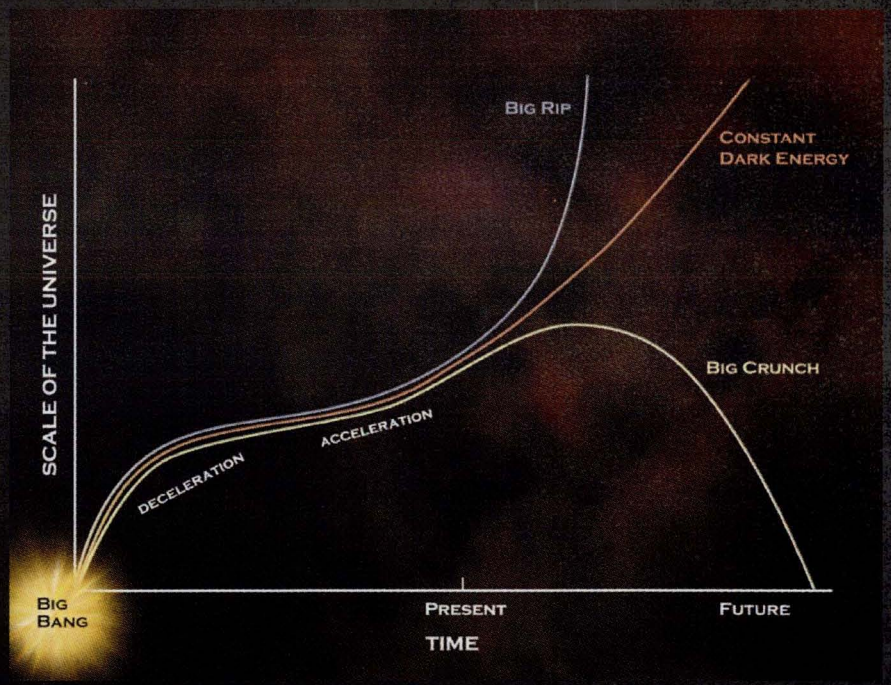


AIAA 2007

1E0657-56 Chandra image with lensing contours

Dark Matter & Dark Energy





The Nobel Prize - 2002

Summary

- Operations are running smoothly
- Mission success
  - Design of the Observatory
  - Excellent and committed staff
  - Team effort
- Exciting and fundamental scientific results
  - Papers at a rate of ~10 per week
- Visit our web site @ www.chandra.harvard.edu

Chandra Lifetime

- Fuel: >40 years
- Orbit: 30-50 years
- Funding: NASA committed to (at least) a 13 year mission